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SPECIAL ISSUE ON MARINE SCIENCES

All Hands on Deck

The urgent work of understanding the world's oceans

Lines in the Water
Communities and scientists explore marine reserves

Down to the Gulf
Tracking whales and toxins

Ocean Views
Eyes on the oceans, 24/7

From Research to Retail
Bringing science and business together for Oregon seafood

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Volume 6 Number 2 // oregonstate.edu/terra // Winter 2011

DEPARTMENTS

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FEATURES

OSU is a leading public research university with more than $275 million in research funding in FY2010. Classified by the Carnegie Foundation for the Advancement of Teaching in its top category (very high research activity), OSU is one of only two American universities to hold the Land-, Sea-, Sun- and Space-Grant designations. OSU comprises 11 academic colleges with strengths in Earth systems, health, entrepreneurship and the arts and sciences.

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Contact Nicolas Houtman at:
nick.houtman@oregonstate.edu
402 Kerr Administration Building
Oregon State University
Corvallis, OR 97331
541.737.0783

On the cover
Photo by Heath Korvola

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SEA CHANGE

My dad navigated merchant ships across the high seas long before his profession became dependent on satellites and GPS. All Karel Houtman needed to know his location was a clear sky, a sextant and a chart. He always felt more comfortable at sea than on land and would steer his way unerringly across the nearly 5,000 water-to-the-horizon miles from Oakland, California, to Yokohama, Japan. For him, driving from home to the grocery store along streets crowded with cars and traffic signs was a journey through a strange land.

Stranger still might be the notion that he could sail on an ice-free Arctic Ocean. As the summer ice pack thins and shrinks, scientists suggest that may be possible in a few decades. Some think it will take less than 10 years.

Karel grew up in The Netherlands and liked to watch ships steaming out to sea. He was less than a block from his California home when he died of a heart attack in 1990. If I could talk to him today, I would tell him of other changes to our oceans: more than half of the world's monitored coral reefs dead or in decline; coastal regions beset by low-oxygen and increasingly acidic water; legendary fisheries that pale against their former abundance; rising wave heights and sea levels that threaten the foundations of coastal communities and ports.

Because I work at a university that focuses on solutions, I would also tell him about signs of hope: research partnerships among scientists, fishermen and government agencies; marine protected areas across the world; recovering whale, seal and sea lion populations; visionary national leadership based in science and collaboration.

It takes a lot more than a sextant to navigate through these and other challenges. As stories in this issue of *Terra* demonstrate, ocean-observing technology has advanced beyond anything my dad could have imagined. With access to up-to-the-minute information about ocean conditions, fishermen will be able to make a living and avoid threatened fish populations. Shippers can save fuel by running with ocean currents and not against them. Engineers will be able to design structures that protect public safety.

If we had a GPS to show us the way, we would probably hear that familiar refrain: "recalibrating route."

Nick Houtman

Nick Houtman, Editor

Hope Rides on Tagged Gray Whale

AN ELECTRONIC TAG ATTACHED TO a single western gray whale may lead to conservation of one of the world's most endangered whale populations. Bruce Mate, director of Oregon State University's Marine Mammal Institute, affixed the tag to the animal, a male known as "Flex," last summer off Sakhalin Island, Russia, in the western Pacific.

Mate has pioneered the tracking of whales through devices that can adhere to whales for hundreds of days, communicate with satellites and relay their locations on a daily basis (see "Tracking the Great Whales," *Terra*, summer 2006). "Not a lot is known about western gray whales, so finding out where they migrate to breed and calve, so we can add some measures of protection, will be a tremendous step forward in their recovery," says Mate.

The international scientific expedition was conducted through the A.N. Severtsov Institute of Ecology and Evolution of the Russian Academy of Sciences and contracted through the International Whaling Commission with funding from Exxon Neftegas Ltd. and the Sakhalin Energy Investment Company.

Undersea Eruptions Led to Massive Landslide

AN ERUPTING UNDERSEA VOLCANO NEAR Guam in the western Pacific continues to reshape the seafloor. In March 2010, scientists from the National Oceanic and Atmospheric Administration and OSU led another in a series of expeditions to NW Rota-1 in the Mariana Arc. Eruptions have been practically continuous since first discovered in 2003, says Bill Chadwick, chief scientist for the project.

In August 2009, intense volcanic activity culminated in a dramatic landslide that extended up to five miles from the top of the mountain. Instruments deployed to monitor volcano activity were destroyed by the avalanche. A hydrophone survived intact and recorded the event, which lasted for five to six hours. The volume of material that slid off the mountain would have filled about 250,000 railroad boxcars, says Chadwick.

Chadwick presented expedition results at the annual meeting of the American Geophysical Union in December.

Lionfish Outcompete the Natives on Coral Reefs

LIONFISH MEMO TO CORAL REEFS in the Bahamas: There's a new predator in town. Native to the South Pacific, the invasive lionfish is reducing the abundance of native fishes on coral reefs in the Bahamas (see "Deep Ecology," in *Terra*, spring 2008). OSU zoologist Mark Hixon leads a team of graduate students and other collaborators working to understand the impacts as well as the factors that naturally control this voracious predator in its native habitat.

In lab and field studies conducted in 2010, they are comparing Bahamian reef systems with and without lionfish and have demonstrated that lionfish outcompete Nassau grouper, which are native to the Bahamas, for access to reef shelters. Lionfish do not eat small grouper, and grouper do not affect lionfish as either a predator or a habitat competitor.

Ongoing studies include lionfish behavior and ecology in the invaded and the native ranges and daily activity observations, as well as patterns of growth and survival.

Smooth Sailing

OREGON HAS BECOME AN INTERNATIONAL CENTER FOR OCEAN RESEARCH

BY MARK FLOYD

For the past decade, Oregon State University has boasted an oceanography program ranked among the top five in the nation, and its broad spectrum of marine and coastal research has an international reputation that few institutions can match.

Federal agencies are funding OSU research on tsunamis, marine ecosystems, wave energy, ocean observing, invasive species and acidification, among other things. In September 2008, the U.S. Department of Energy created a Northwest National Marine Renewable Energy Center at OSU's Hatfield Marine Science Center in Newport, further cementing the university's leadership in wave energy and bringing to $13 million the total amount of funding for the initiative. Researchers are looking at environmental (how will marine organisms respond to subsurface electrical fields?) and technical (what engineered systems will be most effective?) questions and collaborating with state agencies, communities and the private sector.

National Leadership

In 2009, OSU zoology professor Jane Lubchenco became administrator of the National Oceanic and Atmospheric Administration (NOAA) — the second OSU faculty member to hold that position after John Byrne in the 1980s, who later became president of OSU. In addition, Kelly Falkner, former professor in the College of Oceanic and Atmospheric Sciences (COAS), now leads the National Science Foundation's polar research programs. Her COAS colleagues have made similar contributions: Professor Mike Freilich heads NASA's Earth Science Division; Mark Abbott, dean of the college, is a member of the National Science Board, which oversees the NSF and advises Congress and the president; and Emeritus Professor Tim Cowles directs the national Ocean Observatories Initiative. (See "Run Silent, Run Deep," Page 32)

In August 2009, NOAA announced that it would move its Pacific Fleet operations from Seattle to Newport to be adjacent to OSU's Hatfield Center, a stunning economic boon for the mid-Oregon coast that will bring as many as 175 NOAA employees, a half-dozen ships and an annual economic impact in the tens of millions.

Ocean Observing

Shortly after that, NSF announced that OSU would be one of the lead institutions on a $386.4 million Ocean Observatories Initiative that, among other things, will establish a system of surface moorings, seafloor platforms and undersea gliders to monitor the ocean — with a major presence off Newport.

"Oregon State University has perhaps more breadth and depth in marine and coastal science than anyone, and that opens up a lot of doors," says Abbott. "In addition to expertise in many different disciplines, we provide fundamental science, research with direct application, and now we're providing new access to the ocean through ships, satellites, the Ocean Observatories Initiative, gliders, the Marine Mammal Institute and other programs — and we do it on a global scale."

"Sea Cow College"

OSU's emergence as a force in marine and ocean sciences has been in the works for decades. The university came of age as an agricultural institution, developed the top-ranked forestry program in the country, and toward the end of the last century, became an emerging force in engineering. Marine sciences got some recognition, such as when OSU oceanographers discovered the first documented undersea hydrothermal vents and when John Byrne was named NOAA administrator.

But no one ever accused OSU of being a sea cow college. "We've always been the light under the bushel basket," says Abbott. "Face it, fundamental science isn't necessarily sexy. But more and more people are beginning to notice Oregon State because of the volume of high-quality research, our federal leadership, the emergence of programs with applications to real-world problems and that confluence of recent major events."

Oceanography began at OSU in the late 1950s under the leadership of Wayne Burt, but its reach was limited by poor facilities and little access to the ocean. The 16-foot fiberglass boat Burt used in those early days was restricted to Yaquina Bay, and it wasn't until the Office of Naval Research provided a sea-going 80-foot research vessel called the Acona in 1961 that the university was able to attract new ocean scientists, says Byrne.

The R/V Yaquina followed in 1964, and a year later, OSU opened the Hatfield Marine Science Center as a research, education and outreach facility. As both HMSC and COAS grew, the university developed marine science strengths in other areas — marine ecology, fisheries and wildlife, the nationally recognized Oregon Sea Grant program, wave energy, tsunamis and others.

The growth has been nothing short of phenomenal. In 2008-09, Oregon State University spent nearly $100 million on ocean and coastal research — 37 percent of all OSU research expenditures.

And a funny thing happened along the way. Fundamental science has become — if not sexy — at least necessary in the eyes of the public. When the oil tanker *New Carissa* sank near Coos Bay in 1999, OSU physical oceanographers explained where the currents would carry the spilled oil. When the Pacific Ocean off Oregon was first plagued by low-oxygen areas that led to periodic marine "dead zones" in 2001-02, an interdisciplinary team of OSU researchers described the phenomenon and explained its origins.

The 2004 Indian Ocean earthquake and tsunami that killed more than 200,000 people drew comparisons with Oregon's own Cascadia Subduction Zone and brought the university's researchers into the spotlight. OSU's O.H. Hinsdale Wave Research Laboratory includes one of the world's foremost tsunami wave basins.

In 2010, as British Petroleum's Deepwater Horizon well continued to spew oil into the Gulf of Mexico, OSU researchers were documenting the effects. Kim Anderson of OSU's Superfund Research Program established a sensor network to monitor PAHs (petroleum-based compounds) in the air and water. Bruce Mate, director of OSU's Marine Mammal Institute, led efforts to monitor sperm whale movements. Stephen Brandt, director of Oregon Sea Grant, conducted his sixth assessment of fish habitat in the northern Gulf "dead zone."

The strength of OSU's expertise gained additional recognition this year when COAS scientist Kelly Benoit-Bird received a prestigious MacArthur Fellowship, which carried a $500,000 grant for her research. She specializes in the use of acoustics to study marine ecology. (See "Genius of the Sea," Page 22)

Today, Oregon Sea Grant Director Stephen Brandt leads OSU's Marine Council, which aims to enhance and to coordinate a global research enterprise. With scientists conducting studies from the Arctic to the Antarctic, from the North Atlantic to the South Pacific, Oregon State's leadership in international ocean science is literal. terra

OSU MARINE SCIENCE BY THE NUMBERS

CRITICAL MASS

350 OSU faculty engage in marine research and outreach activities.

120 OSU and **180** state and federal researchers collaborate on ocean science at OSU's Hatfield Marine Science Center in Newport.

RESEARCH GRANTS

Nearly **$100 million** in 2008-09, or 37 percent of OSU research expenditures, was directly tied to marine-related issues.

EDUCATION

828 M.S. and **381** Ph.D. degrees have been awarded in ocean and coastal sciences since 1959, complementing marine science options for undergraduates.

HATFIELD MARINE SCIENCE CENTER

On a **49-acre** campus, HMSC supports research in a wide range of ocean sciences.

More than **150,000** people view displays and live-animal touch tanks in the Visitor Center annually.

OREGON SEA GRANT

Among the nation's **32** Sea Grant programs, external reviewers consistently rate Oregon Sea Grant as among the top three.

OCEAN-GOING RESEARCH VESSELS

R/V Wecoma, **185** feet long, **1,100** long tons in normal operations

R/V Pacific Storm, **85** feet long, **153** tons gross

R/V Elakha, **54** feet long, range of **575** miles

Winter Storms Lead to Spring Bloom

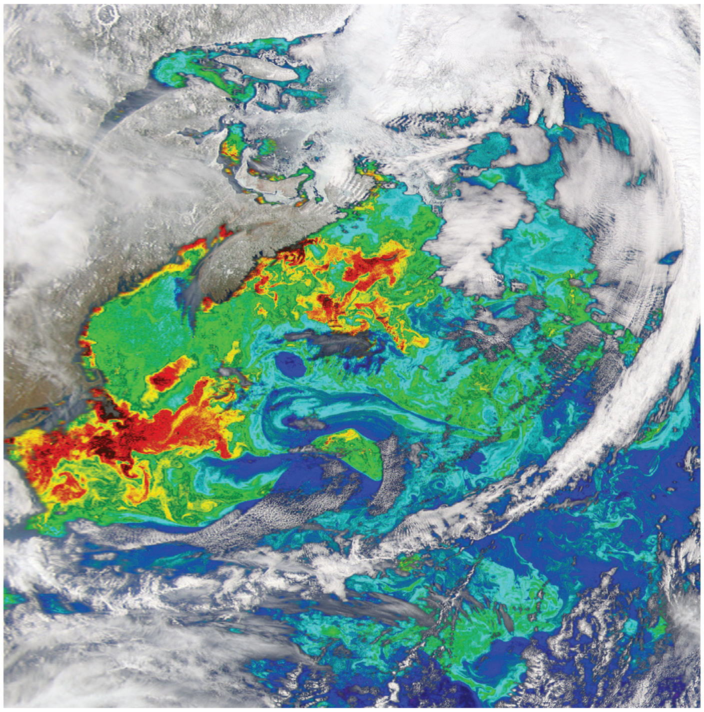
New hypothesis supported by satellites and waterborne sensors

IF YOU SEPARATE PREDATORS FROM their prey, you get more prey. Now that simple relationship has been used to explain one of the most important annual events in the ocean: the North Atlantic spring phytoplankton bloom.

Since the 19th century, oceanographers have sought to explain its origins and have settled on the wintertime mixing of ocean waters followed by increasing light and temperature in the spring, a process known as Sverdrup's hypothesis.

However, using NASA satellite data, Michael Behrenfeld, OSU professor in the Department of Botany and Plant Pathology, reported in 2010 that phytoplankton abundance begins to increase in the depths of winter, well before light and warmth return. He offered another explanation: As winter storms stir the water, predators of phytoplankton get separated from their prey, allowing more of the tiny plants to survive and initiating a bloom that lasts until the end of spring.

Critics who took issue with Behrenfeld's use of satellite data noted that space-borne sensors capture light from only the ocean surface. However, in a second 2010 paper, Emmanual Boss of the University of Maine and Behrenfeld used additional data from a waterborne "profiling float" that sampled from deep in the ocean to the surface. They reported in the journal *Geophysical Research Letters* that float and satellite data are consistent. Phytoplankton begin to rebound in the short, dark days of winter. Move over Dr. Sverdrup.



Highest chlorophyll concentrations show as red in this spring 2003 image. The East Coast — Long Island, the Gulf of Maine and Nova Scotia — is to the left. (Image courtesy of the SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE)

Shellfish on Acid

How will acidic water affect Oregon's shellfish industry?

"O Oysters," said the Carpenter,
"You've had a pleasant run!
Shall we be trotting home again?"
But answer came there none —
And this was scarcely odd, because
They'd eaten every one.

— LEWIS CARROLL
THE WALRUS AND THE CARPENTER

WHETHER OR NOT YOU'RE A fan of gulping down raw oysters doused with Tabasco, recent declines in the succulent Northwest shellfish are cause for alarm. That's because the chemical changes in seawater that are harming oysters could have far-reaching effects on other ocean species as well (see "Tipping Point," Page 12).

A few years ago in Tillamook, oyster larvae at the Whiskey Creek Shellfish Hatchery were mysteriously dying. OSU scientists diagnosed the problem: acidic seawater, which disrupts the formation of calcium carbonate, the hardening compound in shells and corals. Researchers helped the growers make adjustments in their operation to reduce the influx of acidic water.

Now, with support from the National Science Foundation, oceanographers George Waldbusser, Burke Hales and Brian Haley in OSU's College of Oceanic and Atmospheric Sciences and Chris Langdon of the Mulluscan Broodstock Program at Hatfield Marine Science Center are running experiments to find the threshold at which oysters, clams and mussels are harmed by acidification.

"Scientists know very little, to date, about specific modes of action triggered by acidification," Waldbusser says.

(Photo: Alex Staroseltsev)

Fish on the Run

Once overharvested, the yellow tang has rebounded

NOT TOO LONG AGO, HAWAII'S Kona Coast was known as the Gold Coast — not for its moneyed landowners but for a golden fish called the yellow tang. These small, butter-colored fish once flashed in the surf by the hundreds of thousands. But aquarium hunters decimated the tang, which can live 40 years in the wild. So, Hawaii established a necklace of protected sites along the coastline in 1999.

Since then, tang living in Hawaii's marine reserves — areas off-limits to fishing — have not only rebounded locally, their larvae have "spilled over" into distant areas, OSU researchers have discovered. Larvae the size of rice grains can drift more than 100 miles and then grow into healthy adults, marine ecologist Mark Hixon and postdoctoral researcher Mark Christie learned through advanced genetic testing and sophisticated statistical analysis. This is some of the first direct evidence that larvae can "re-seed" fish stocks many miles from their origins.

"This approach will provide valuable information to help optimize the placement of reserves, identify the boundaries of fishery stocks and other applications," says Hixon.

New Courses Explore Ocean Cultures

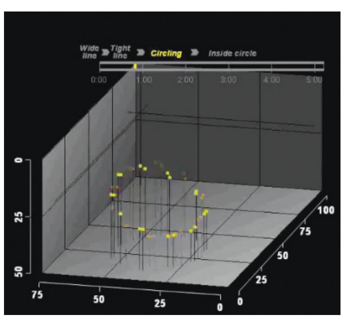
CENTURIES BEFORE MODERN SCIENCE, HUMANS traveled, exploited, contemplated and celebrated the seas as explorers, fishermen, whalers, merchants, poets, storytellers, musicians and philosophers. Two new courses sponsored by OSU's Spring Creek Program and Environmental Leadership Institute will delve into this ancient human-ocean relationship.

Inspired by the university's upcoming symposium, Song for the Blue Ocean: Science, Art and Ethics (February 18 – 19), "Literature of the Ocean" will "pursue the subject across time as well as through the three-dimensional space of the sea," says English Assistant Professor Peter Betjemann. Literary readings focus on oceanic zones (littoral, neritic, oceanic) as well as levels within the water column (surface, photic, aphotic) and places where human communities meet the sea (wharves, docks, beaches). The course, ENG 499/582, is being taught winter term.

A joint colloquium in anthropology and zoology will explore the relative strengths, weaknesses and assumptions of the worldviews underlying traditional ecological knowledge (TEK) and Western scientific knowledge (WSK). "Ocean Wisdom: Integrating Traditional and Western Ecological Knowledge of the Pacific," will focus on the Pacific Ocean and its bordering lands. "Students will compare and contrast the different epistemologies on which TEK and WSK are based via case studies throughout the Pacific region," says marine ecologist Mark Hixon, who will team teach the class with anthropologist Deanna Kingston. ANTH/Z 499H will be offered spring term.

On the Web

KIDS ARE NATURAL SCIENTISTS, BURSTING with curiosity about the natural world. When science instruction taps into that inquisitiveness in engaging ways, students can get hooked on the wonder of it all. *Terra* has launched a new Web page where K-12 students and teachers will find kid-friendly articles about OSU research, as well as classroom activities created with Oregon science standards in mind. Find an article and project on tsunamis at Terra for Kids.



KELLY BENOIT-BIRD IS MORE THAN a marine ecologist. She combines sonar echoes to create 3-D composite images and animates her data to reveal patterns in animal behavior. Watch videos that show dolphins forage in a pack, circle their prey and dart into a ball of fish to feed.

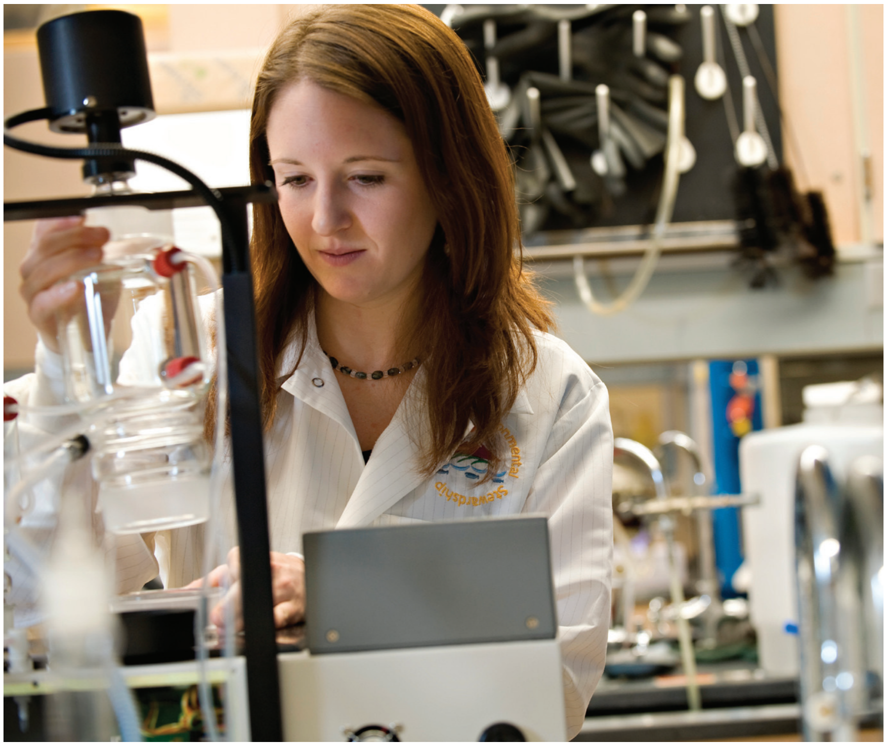
AS CLEAN-UP CREWS FRANTICALLY WORKED to minimize damage from the Deepwater Horizon well blowout in the Gulf of Mexico, Justin Bailie, a photographer from Seaside, Oregon, was capturing scenes from a Gulf community. His slideshow demonstrates residents' strong ties to the sea and their distress over the oil spill.

JOIN A VIRTUAL RESEARCH VOYAGE aboard a Boston Whaler at Port Orford with OSU researchers Scott Heppell and Tom Calvanese. Zoom out with them to a reef called Redfish Rocks, site of one of Oregon's first two pilot reserves. As the boat rocks madly, watch the scientists surgically implant a radio "tag" into a rockfish for tracking with hydrophones arrayed around the reef.

After the Spill

Sarah Allan is tracking toxins

BY CELENE CARILLO



Studying PAHs at the Portland harbor Superfund site helped to prepare Sarah Allan and other students in Kim Anderson's lab for an ongoing role in the Gulf of Mexico. (Photo: Karl Maasdam)

THE 2010 OIL SPILL IN the Gulf of Mexico brought up bad memories for Sarah Allan. The Oregon State University Ph.D. student, who grew up in southeast Alaska, was a child in 1988, when the *Exxon Valdez* struck a reef and dumped millions of gallons of crude into another rich marine ecosystem, Prince William Sound. Allan remembers sea otters and other charismatic species dying in droves and coastal businesses being devastated.

"I was flabbergasted," says Allan, who studies toxicology. "I thought, 'Wow, 20 years later, and we're doing exactly the same thing.' It was really depressing to see it happen again, but I've been in school for a long time precisely so I can have some positive impact when things like this happen."

That drive led Allan to Kim Anderson, OSU professor of environmental and molecular toxicology, who investigates compounds known as polycyclic aromatic hydrocarbons (PAHs). Anderson's lab focuses on where PAHs come from, how they move and are transformed in the environment and what happens when humans and other organisms are exposed to them.

Composed of more than 100 different compounds, PAHs are part of fossil fuels and a product of combustion. Some cause cancer, birth defects and other health problems. To understand these chemicals, Allan melds her biology background with the growing cache of analytical chemistry skills that she is developing in Anderson's lab.

Crude Consequences

In May 2010, Allan and other members of the lab went to the Gulf of Mexico to apply their PAH expertise to the expanding oil spill. Since then, the group has made more than half a dozen visits to monitor PAHs in the air and water at four locations from Pensacola, Florida, to Grand Isle, Louisiana.

The OSU researchers watched the disaster unfold first-hand. They saw gobs of oil washing up on the shores of wildlife sanctuaries and cleanup crews working 24 hours a day, rescuers bringing oiled animals to docks to be cleaned and dolphins jumping in oil slicks. They watched the people of the Gulf Coast grow more and more distressed. "You could see the impact on people go from, 'Well, maybe it won't be that bad,' to 'Should we take a settlement? I'm out of work. What do we do?'" says Allan.

Allan and others on Anderson's team set up "passive sampling devices," which they developed to use a membrane that can be "tuned" to detect specific classes of chemicals. Designed to mimic cell membranes and fatty tissues in animals, they represent the potential for biological exposure. Back at the lab in Corvallis, Allan analyzes the samples to determine the concentration of PAHs in the environment. In OSU's Sinnhuber Aquatic Research Laboratory, she also investigates PAH toxicity by studying how the chemicals affect developing zebrafish embryos.

Communicating science to the public — from park managers to fishermen — is an important task for Allan, especially in a traumatized place like the Gulf. "We have lots of really good scientists doing lots of good work," says Allan. "But it isn't usually communicated well. I'd like to be on the communication end of science."

According to Anderson, Allan would do well in such a role. "It would have been difficult to send a crew to the Gulf without someone with good leadership qualities," says Anderson, who was not always available to travel with the group. "She understands the big picture."

ON THE WEB: more on the spill and PAHs at *oregonstate.edu/superfund/oilspill*

Raised Voices

Sea Grant Extension helps communities address problems

BY NICK HOUTMAN

"Fishermen are an extremely curious group. That's their nature. And they have a hell of a lot of knowledge," says Jeff Feldner. (Photo: Lynn Ketchum)

FISHING IS HARD ENOUGH. The weather, changing ocean conditions and the fickleness of fish make it tough to track your quarry let alone catch them. Now competition for space in the ocean — an oxymoron in an environment defined by its seemingly limitless expanse — poses new concerns along the West Coast. In the future, fishermen will jostle with wave energy parks, marine reserves and aquaculture for space to troll for shrimp, drop crab pots or cast lines for rockfish.

Jeff Feldner knows what's at stake: individual livelihoods, coastal communities and the resources that support them. The Newport-based Oregon Sea Grant Extension educator bought his first fishing boat in 1973. A few years earlier, on the lookout for a career change (he has a chemical engineering degree from the University of Minnesota), he had come to Newport at the invitation of a salmon fisherman. After a day at sea, he was hooked. "I've been fishing forever," he says, as though life began the moment he crossed the Yaquina River Bar into the Pacific.

Feldner still fishes part-time, processes his catch in a cooperatively owned South Beach packing plant and tests consumer response to new marketing methods. He has always kept an eye on the bigger issues that define the industry. Tensions over gear restrictions, by-catch (the non-targeted fish that come up in nets) and closed seasons drove him to serve a nine-year stint on the Oregon Fish and Wildlife Commission. Now, he is one of 15 Sea Grant specialists and educators from Brookings to Astoria, who work with individuals and with community organizations to address coastal issues through dialog and collaborative science.

"We are the go-between between the seafood industry and fishery science or fishery management," says Feldner. He and his Sea Grant colleagues Kaety Hildenbrand, Flaxen Conway, Jamie Doyle and others help community groups participate in decision-making processes on topics such as marine reserves and wave energy. In 2010, they helped facilitate a conference among scientists and the fishing industry on another contentious topic, off-shore aquaculture. They are addressing invasive species that upset coastal ecosystems and hazards such as eroding shorelines and tsunami risks.

"Sea Grant Extension distinguishes itself in public engagement," says Dave Hansen, Extension program leader based in Corvallis. "The marine reserves process is a good example, where, in a pretty hot political and emotional situation, we tried to be the convener that everybody could trust, that didn't have a secret agenda."

In 2008, Feldner and former Sea Grant Extension agent Ginny Goblirsch coordinated a series of eight coast-wide "listening and learning" sessions on marine reserves. "When the process ended, the governor changed course," says Feldner, "slowed down the process, basically said it was going to take at least another two years, and put in place a process to ensure more community based input – essentially moving more toward a bottom-up process rather than a top-down one."

Oregon's tradition of strong community participation in resource management has drawn national attention, says Hansen, who came to Sea Grant in 2010 from Delaware. "There is a tremendous amount of community interest in decisions here. Nothing just slides through," he adds. "People seem to have their fingers on the pulse of what's going on."

And new developments in science and technology will continue to fuel that interest. Tomorrow's fishermen will have access to more accurate information about fish stocks, ocean conditions and markets, says Feldner. They'll be able to harvest more efficiently, protect threatened species and offer consumers a high-quality local product at the same time. "There's nothing static in fishing," he says.

Down to the Gulf

BY NICK HOUTMAN

Bruce Mate didn't wait long. Within days of the April 20 Deepwater Horizon oil well blowout in the Gulf of Mexico, he was on the phone with officials from the U.S. Minerals Management Service. From 2001-2004, the agency had funded him to study the Gulf's endangered sperm whales. Now, the director of Oregon State University's Marine Mammal Institute had an idea: By tracking the sperm whales again, he could provide useful data to federal agencies and the well's owner, British Petroleum, on the impact of spilled oil on the marine ecosystem.

Working through an emergency-response process known as Natural Resource Damage Assessment, Mate negotiated a contract with BP in which OSU would own the data. BP and the National Marine Fisheries Service would have access to determine damages for future settlements. By the end of May, Mate and institute staff members Craig Hayslip and Ladd Irvine were on the research ship *Gordon Gunter* (owned by the National Oceanic and Atmospheric Administration), which had been quickly re-tasked from the North Atlantic to support five spill-related science missions.

Mate wasn't the only OSU researcher to respond as the world watched crude spew into what the Census of Marine Life has ranked as one of the globe's most diverse marine systems. Professor Kim Anderson in the university's Superfund Research Program marshaled a crew to track chemical contamination along the shore. At four sites from Pensacola, Florida, to Grand Isle, Louisiana, they deployed devices that essentially sniff the air and water for an oil component known as polycyclic aromatic hydrocarbons, or PAHs. And in September, a team led by Stephen Brandt, director of Oregon Sea Grant, conducted an acoustic survey of fish in an area northwest of the spill site.

Researchers are still analyzing data, and while images of oil-soaked pelicans, turtles and other animals are seared in the public mind, it will be a while before the broader biological significance of the spill is known.

Following the Whales

In late December, Mate was following six of the dozen whales that he had tagged in June near the damaged well. One of them was among 58 that he had tagged in the previous project. Data from that effort, he says, form a baseline, which can be used to compare whale behavior after the 2010 spill.

"I don't expect to see sperm whales directly affected by oil," Mate says, "but if oil or dispersants have dramatically affected the squid they eat, the secondary effect will likely influence the movements of the whales. They sort of vote with their flukes."

A pioneer in satellite-based whale tracking, Mate says the whales that had initially traveled northeast from the well (in the direction of oil visible at the surface) had changed course and were in the western Gulf, some close to the Mexican coast. As his lab continues to monitor whale movements, researchers will use the data to analyze the size of the whales' home ranges. They'll also consider whether significant differences between 2010 and previous years suggest that whales avoided heavily oiled waters.

Pollutants on the Increase

While Mate was making his plans, Kim Anderson in OSU's Department of Environmental and Molecular Toxicology was assembling sampling devices and personnel to track PAHs,

Research vessels in the northern Gulf are never far from the more than 4,000 active oil and gas platforms in the area. (Photo: Stephen Brandt)

a group of more than 100 compounds that the U.S. Environmental Protection Agency classifies as "highly potent carcinogens."

Supported by OSU's Environmental Health Sciences Center, Anderson and her team, including Ph.D. student Sarah Allan (see "After the Spill," Page 8), started deploying their equipment on May 9, before oil began washing ashore. As the oil slicks and tarballs hit beaches and wetlands through the summer, PAH concentrations rose to about 40 times over baseline levels, according to preliminary data.

"There are a range of health effects associated with PAHs," says Anderson. "They are toxic by several different modes of action. We're now using a technique that looks at the fraction of PAHs that are bioavailable — that have the potential to move into the food chain."

Over the next two years, with support from a National Institute of Environmental Health Sciences grant, the lab will continue sampling in each location for more than 1,200 different compounds: PAHs, pesticides, PCBs and other industrial chemicals, many of which are known to disrupt hormone signaling.

Fish-Eye View

For Stephen Brandt, oil is only one of the threats to fish habitat in the Gulf of Mexico. At least as significant is the persistent presence of a low-oxygen region west of the Mississippi River outlet, a.k.a., the "dead zone." As part of a multi-institution project that began in 2003, Brandt has collected data on water quality and fish behavior in order to assess the dead zone's impact on fisheries.

A pioneer in the use of acoustics to study fish, Brandt has led five sampling expeditions to the Gulf. His September cruise, with OSU faculty research assistants Sarah Kolesar and Cynthia Sellinger, was the first after a major oil spill, but it was not the first to reflect the presence of crude. Natural oil seeps pour an estimated 41 million gallons into the Gulf every year, he points out.

During eight days of sampling, Brandt and his team saw no oil, but they did see evidence for the first time of "a very intense double-layered dead zone" with low-oxygen patches near the bottom as well as higher in the water column. The location and severity of low-oxygen zones can shift from day to day. It will take additional data analysis to identify the factors behind the 2010 pattern.

Brandt knows it will take time for the Gulf's rich marine life to respond. In 1979, the region received a large gush of crude from Mexico's Ixtoc 1 well, which fouled beaches and estuaries from Texas to the Yucatán Peninsula. After that event, it took three to five years for fisheries to come back, he says. Some species, he adds, may never recover. terra

ON THE WEB: see the locations of Kim Anderson's PAH sampling stations at ***oregonstate.edu/superfund/oilspill***, and a video of Stephen Brandt's Corvallis Science Pub presentation, Troubled Waters, at ***ustream.tv/recorded/10729249***.

Tipping Point

West Coast research consortium tackles ocean acidification

BY NICK HOUTMAN | PHOTO BY CRISTINE MCCONNELL

In the summer, you may have to go 20 miles out to sea to find it, but close to the seafloor, near the edge of Oregon's continental shelf, is a preview of the future: water as acidic as what the world's oceans may be like in 50 to 100 years. "The future of ocean acidification is already here off the Ocean coast," says Oregon State University oceanographer Francis Chan.

On a global basis, ocean acidity has increased about 30 percent since the start of the Industrial Revolution. So what, you might ask? The problem lies in basic chemistry: carbon dioxide (CO_2) in the air mixes into seawater and, through a series of reactions, weakens calcium carbonate structures such as shells and coral reefs. In addition, recent studies suggest that increasing acidity (carbon dioxide forms carbonic acid in water) interferes with the ability of corals, sea urchins and other creatures to regulate functions from metabolism to reproduction.

Not all parts of the ocean are equally vulnerable, says Chan, an assistant professor of zoology. "Some places are going to be pretty resilient. They won't feel the effects (of increasing acidity) for many decades or even a couple of hundred years. But there are other areas where people have said we really need to pay attention, that will be early warning systems, the canary in the coal mine."

Two Sides of the Same Coin

The West Coast is one of those areas, and what makes it so vulnerable, says Chan, is the cold, deep water that swimmers in Oregon encounter during the summer. As north winds push warmer surface water away from the shoreline and out to sea, cold water comes up from offshore to replace it. This water tends to be more acidic and lower in oxygen than surface water, and as if adding insult to injury, it is loaded with nutrients that, under the right conditions, feed massive plankton blooms and set the stage for the so-called "dead zone" that has occurred regularly off Oregon since 2002.

Scientists define a dead zone as water with little oxygen, less than two parts per million to be precise (a condition known as "hypoxia"). As microbes chew away on dead plankton, they drop oxygen levels further still. "Hypoxia and acidification are opposite sides of the same coin," says Chan. The microbes that feed on plankton blooms also release carbon-dioxide and make the water more acidic.

Since April 2009, Chan and colleagues in the Partnership for Interdisciplinary Studies of Coastal Oceans, or PISCO, have been measuring just how acidic this water gets. From a station just offshore of Strawberry Hill State Park, ("a long fly ball from the surf zone," says Chan) to about 20 miles out, they have placed sensors that record CO_2 (actually, pCO_2, or the partial pressure of CO_2 in the water, a measure of its concentration) and pH. They have found that upwelling water can contain from 150 to 1,450 microatmospheres, reaching levels nearly four times the global average. At the same time, pH levels can drop as low as 7.5. Such corrosive conditions can last for up to five months during the summer and fall.

Limits to Growth

Through PISCO (see sidebar), scientists are working to understand how sea urchins and mussels are responding to these variable conditions and how they might adapt in a warmer, more acidic future. "They already may be close to their acclimatization or adaptational capacity," says Bruce Menge, OSU distinguished professor of zoology and lead scientist on the project, "and thus may have limited ability to respond to additional increases in CO_2."

Monitoring the West Coast's pH "climate" is a high priority. To complement the Oregon data from Strawberry Point, scientists will establish stations off Southern and Northern California. In addition, researchers at UC Santa Barbara and the UC Davis Bodega Marine Lab will raise sea urchins and mussels in laboratory tanks, expose both larvae and adults to increasing CO_2 and analyze differences in gene function. By using multiple sites, the project will evaluate the likely future for urchins and mussels across a wide range of ocean conditions.

"Here are organisms that we've studied for decades," says Chan, "and we know the important roles they have in structuring the communities we see out there. We know they're important players in the coastal ecosystem."

"For the first time," adds Menge, "we will be able to examine the genetics and ecology of these key organisms to see how populations that span over a thousand miles of coastline are coping with changes in ocean chemistry." terra

ON THE WEB: See more on the science of ocean acidification at *piscoweb.org/topics/climate-change/ocean-acidification*

A Regional Consortium

FRANCIS CHAN AND HIS OSU colleagues Bruce Menge (distinguished professor of zoology) and Jack Barth (professor of oceanic and atmospheric sciences) have marshaled the expertise of a regional scientific consortium to understand ocean acidification on the West Coast. Through the Partnership for Interdisciplinary Studies of Coastal Oceans, or PISCO, they are collaborating with scientists at six other institutions — UC Santa Barbara; Stanford; UC Santa Cruz; UC Davis, Bodega Marine Laboratory; University of Hawaii; and the Monterey Bay Aquarium Research Institute.

Last fall, the National Science Foundation awarded a $2 million grant to the project, "Acclimation and adaptation to ocean acidification of key ecosystem components in the California Current System." Researchers will conduct experiments on how acidification will affect two of the region's signature marine organisms: sea urchins and mussels. Menge is the lead principal investigator. Collaborators include 13 other scientists at OSU and partner institutions. (For another NSF-funded ocean acidification project, see "Shellfish on Acid," Page 6)

PISCO has received primary financial support from the David and Lucile Packard Foundation and the Gordon and Betty Moore Foundation.

Lines in the Water

Communities and scientists explore proposed marine reserves

BY LEE SHERMAN

Performing surgery on a fish is tricky enough. But when the surgeon wields his scalpel while kneeling in a boat that's bucking like a mechanical bull, the task requires a whole new level of finesse.

One high-overcast afternoon off the shores of Port Orford, that's exactly what Oregon State University researchers Scott Heppell and Tom Calvanese are about to do. They have motored out to a rocky reef in pursuit of five species of rockfish — blacks, canaries, Chinas, coppers, quillbacks — and a species of sculpin called a cabezon, for implantation with acoustic monitoring tags. Idling their outboard motor inside a cluster of craggy outcroppings known as Redfish Rocks, the men brace themselves in the bow of a heaving Boston Whaler named *OSU Fisheries & Wildlife*. Each man drops a hook and line into the ocean.

The rockfish are biting like crazy. Over and over, the researchers reel them in, only to find that they're members of non-targeted species. "Another blue," Heppell grouses after releasing the fourth grayish-blue specimen. Then his pole arcs hard as another fish takes his bait. He draws it to the side of the boat. "It's a black!" he announces.

He gently unhooks the steel-gray fish whose spiny head looks like a Japanese fan unfurled. "All species of rockfish are beautiful," he observes. "Their genus name, *Sebastes*, is Greek for 'magnificent'."

After a couple of false starts when the slippery animal writhes out of his hands and flops onto the floor of the boat, he and Calvanese invert the fish onto the "surgery cradle," a v-shaped acetate device custom-made for this procedure. The fish lies still as Calvanese bathes its gills with fresh seawater to keep them wet and oxygenated. Working fast, Heppell makes a half-inch incision in the body wall, avoiding the liver. He sterilizes a black plastic cylinder about the size of a ballpoint-pen cap and tucks it into the tiny opening. Every few minutes, the battery-powered electronic device sends out an acoustic signal uniquely coded for that individual fish. A series of underwater microphones, which Calvanese previously deployed around the reef's perimeter, will pick up the ultrasonic pinging from the fish's transmitter and store the data, allowing the researchers to track its movements over the coming year.

Still unfazed by the boat's rocking motion, Heppell takes a couple of deft stitches with a nylon thread to

With Redfish Rocks in the distance, Port Orford fishermen prepare for a day at sea. (Photo: Heath Korvola)

Redfish Rocks, a temperate reef just offshore at Port Orford, is under study as one of Oregon's two pilot marine reserves (Photo: Heath Korvola).

close the wound, applies an antibiotic, and sets the fish carefully inside a pyramid-shaped wire cage attached to a 50-foot yellow rope. He and Calvanese lower the cage, which is equipped with a miniature camera, into the depths of the reef. They watch the fish's behavior on a small monitor mounted on the dashboard, holding their breath. Despite the trauma of surgery, 98 percent of tagged fish survive, studies have shown.

"OK, he's swimming," Heppell says a few moments later.

The researchers pull a release lever, and the cage pops open. The black rockfish — one of seven fish tagged that day — returns to the reef, where it could live for 50 years or more.

The study — which Calvanese is conducting in collaboration with local fishermen for his master's degree in Marine Resource Management — is part of a massive multi-institution research undertaking at Redfish Rocks, one of two pilot sites that were set aside as no-fishing zones called "marine reserves" in 2008 by the Legislature on the recommendation of Oregon's Ocean Policy Advisory Council (OPAC). Scientists like Calvanese and Heppell, an assistant professor in OSU's Department of Fisheries and Wildlife, are studying the cold-water reef ecosystem for data that will form a baseline "snapshot" against which future findings can be compared.

OPAC's overarching research question is, Can marine reserves help protect biodiversity, marine habitats and areas important to marine fisheries in Oregon's coastal waters? If so, how big should the no-fishing zones be for optimal effectiveness? Tracking rockfish is one way to find out.

"With acoustic tracking, we can see the fish's home-range patterns," says Heppell. "How far does a fish move in a day? How far does it move over the course of a season? How often does it swim outside the protection of the reserve? From a management perspective, this study will let us know how often and how long the fish are vulnerable to harvest."

These are questions that have engaged oceanographers, marine biologists and Sea Grant Extension agents at OSU for at least a decade. Despite strong scientific evidence that marine reserves, when well designed and carefully monitored, provide safe haven for fish, thus allowing dwindling populations to rebound, many Oregon fishermen perceive them as threats to their livelihood. If fishermen don't buy in, reserves won't work, research shows.

"The first element of marine reserve success is that people don't fish there," says OSU's Selina Heppell, an associate professor in the Department of Fisheries and Wildlife who sits on OPAC's Science and Technical Advisory Committee (and is married to Scott Heppell). "Biological response, economic benefits — those all come later. If you put lines on a map and people ignore them, your reserve is a failure."

The fate of marine reserves in Oregon, it turns out, hinges not only on science, but also on buy-in from a host of stakeholders: commercial and recreational fishermen, environmentalists, business proprietors, local government, property owners and coastal communities. Port Orford, with its thriving reef at Redfish Rocks, has been at the forefront of getting that buy-in.

Diving for Data

One recent wind-lashed morning, Alix Laferriere finds herself ashore, stuck at a desk. "The seas are too high for sampling," the biologist grumbles from her Newport office.

As soon as the swells subside, she'll be back aboard a boat overseeing deployment of scuba divers to install an underwater electronic device to record water temperature and light hourly for six months. All sorts of other high-tech scientific gear — high-def cameras, laser equipment, a remotely operated vehicle named Sea Cow — will be used throughout the winter as weather allows. Laferriere's job at the Oregon Department of Fish and Wildlife (ODFW) is to coordinate scientific studies testing the effectiveness of Oregon's marine reserves. Data and technical support from OSU-based PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans) are contributing to the pool of findings along with OSU scientists Scott and Selina Heppell and Calvanese. Marine geologist Chris Goldfinger has mapped Redfish Rocks with underwater imaging technologies. Marine ecologist Mark Hixon has provided leadership on the national, state and local levels. Oregon Sea Grant has studied the socioeconomic impacts of marine reserves as well as serving as a neutral convener for community dialog.

When half a dozen divers — on contract to the ODFW from UC Santa Cruz — flop tanks-first off the boat and disappear, one by one, into the waters at Redfish Rocks or when the agency's $20,000 pressurized videocam is gentled toward the seafloor on its tether, the human researchers and their sophisticated hardware sink into a silent world of kelp forests undulating in the current, of massive, algae-mottled boulders festooned with scarlet sea stars and giant, snow-white anemones, of sand-dollar beds and colonies of Crayola-colored sea pens, of big-eyed rockfish grazing on plankton with dour mouths, of sea lions churning round and round in the murk, eyeing the divers curiously.

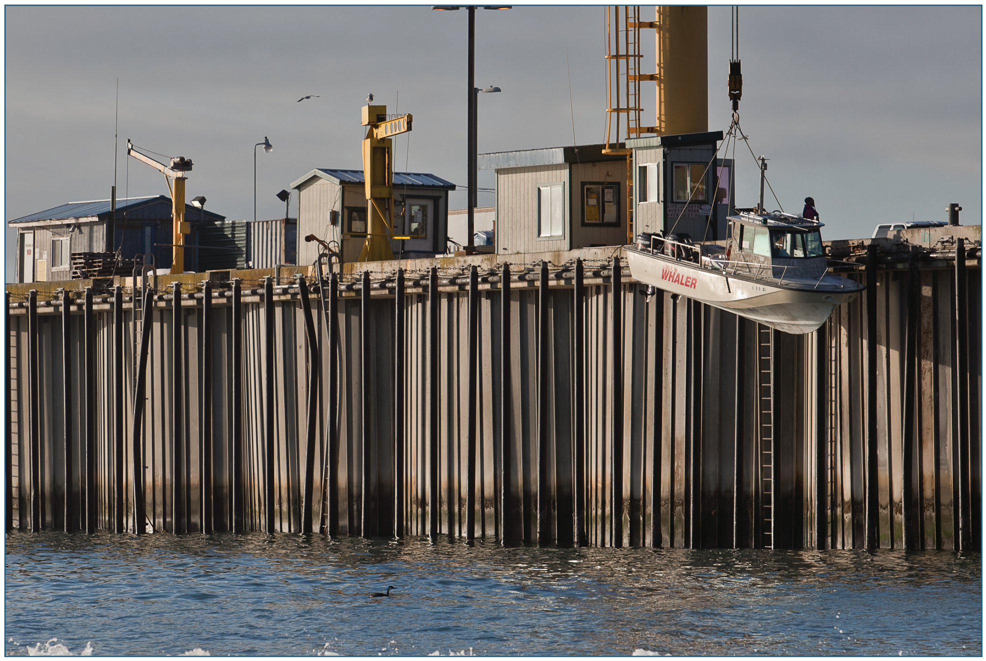
"We've collected an amazing amount of information to characterize the site," says Laferriere. "We're collecting data on seafloor structure, on ocean conditions — temperature, salinity, chlorophyll, dissolved oxygen — and on the abundance and distribution of algal, invertebrate and fish species."

As biological research leader for Oregon's marine reserves, Laferriere gives regular updates to the Redfish Rocks community team — about 20 people from all walks of coastal life, from business and politics to charter and commercial fishing to science and conservation. Underwater videos are a highlight of her reports. On the first Monday in October, team members who are gathered at Port Orford City Hall for their monthly meeting watch with interest as the reef comes alive on a big screen. A rock face bristling with spiny urchins sheers off steeply to depths of 65 feet. Giant, ghostly anemones cling to the submerged cliffs. Divers swim in waters as green as tea (a "mega-bloom of mysid shrimp" lends the water its "eerie" green tinge, Laferriere remarks) as they inventory resident species, from invertebrates to fish to marine mammals. They record their observations on waterproof slates.

In Brief

THE ISSUE Marine reserves could help sustain Oregon's fishing industry and near-shore ecosystems, but agreement is lacking on their management, costs and benefits. In coordination with a community planning process, the Legislature has funded studies of five locations to determine how Oregon's reserves would affect marine ecosystems and coastal communities.

OSU LEADERSHIP OSU researchers are studying rockfish movements in a pilot marine reserve at Port Orford and generating information for the Oregon Department of Fish and Wildlife to use in assessing the social, economic and biological consequences of each proposed reserve. Community meetings have been held to provide individuals with opportunities to comment.



As the West Coast's only dry dock, Port Orford launches fishing boats by crane (Photo: Heath Korvola).

James "Jimbo" Jennings, owner and captain of the vessel My Girl, *voices mixed feelings about reserves as a member of the Redfish Rocks Community Team (Photo: Justin Smith).*

"The whole time we were out, a gray whale was playing around," Laferriere tells the team. "The place is obviously alive."

But on this particular Monday night, the serene ocean imagery soon gives way to a testy tone. James "Jimbo" Jennings, one of three fishermen on the team, is feeling frustrated. Like many fishermen up and down the Oregon Coast, Jennings worries that reserves will hamstring a commercial fishing industry already tangled in a phalanx of state and federal rules restricting catches and seasons. Wave-energy parks, wind turbines and fish farms are sure to carve up and close off even more ocean real estate in coming years.

The fear starts with dollars and cents ("How hard can you squeeze a fisherman till he can't make a living?" he demands). But it goes deeper. The team's grand vision for the port — to build a research field station on the dock and a marine interpretive center for tourists — threatens to alter Port Orford's character in ways that could marginalize the fleet, says Jennings, owner and skipper of a 34-foot vessel named *My Girl*. He complains about the "Disneyland effect" of tourism and the ivory tower of science, contrasting those endeavors against the practical, putting-food-on-the-table impact of fishing. Port manager Gary Anderson chimes in angrily, railing against proposals that he predicts will infect the traditional fishermen's dock with alien interests. David Smith, president of the local chamber of commerce, sympathizes with the fishermen's concerns, but argues for the economic opportunities and diversification that tourism and research would bring to a slumping economy. Jennings fires back, offering a paean to the fisherman's critical role in feeding the world that ends with a plea to safeguard an ancient way of life.

"I think you're throwing out a culture," Jennings tells the members gathered around the table.

Political Ecology of Fishing

This core conflict — the survival of ocean ecosystems versus the survival of human economies and traditions — is at the crux of Oregon's community team process, which the Legislature laid out in House Bill 3013 passed in 2008. The act not only established pilot marine reserves at Redfish Rocks and Otter Rock but also charged ODFW with studying the potential of three additional reserves — Cape Falcon, Cascade Head and Cape Perpetua. A fourth reserve at Cape Arago-Seven Devils was pegged for preliminary discussion.

Biology was only half the mandate. The other half was sociology. ODFW was tasked with assessing the impact of marine reserves on local livelihoods as well as on ocean ecosystems. To make sure all points of view were honored, community teams had to represent all stakeholders, from commercial and recreational fishermen to conservationists to scientists and local leaders.

These disparate voices are full-throated on this Monday-night meeting in Port Orford. The contentiousness catches everyone by surprise. While other coastal communities have fought bitterly against the concept of no-fishing zones, Port Orford has been the poster child of civility and open-mindedness in the state's marine reserve debate.

OSU researcher Mark Hixon has been at the frontlines of the battle since the beginning.

"Oregon is way behind most other states in establishing marine reserves — and definitely way behind the other Pacific states of Hawaii, Alaska, Washington and California," says Hixon, who chaired the national Marine Protected Areas Federal Advisory Committee before taking on the co-chairmanship of Oregon's Cape Perpetua community team. "The simple reason is that there's great resistance by the fishing community in Oregon."

Redfish Rocks team member Dave Lacey, an organizer for the nonprofit environmental group Our Ocean, has felt the bitter resistance first-hand. A former commercial fisherman who spent a season tending gear for divers harvesting sea urchins and another catching rockfish at Port Orford and Gold Beach, Lacey saw both fisheries crash beneath him. The demand for urchins bottomed out when tottering Asian economies made the delicacy unaffordable. Then the groundfish collapse of 2000 — when the U.S. Secretary of Commerce declared the fishery a disaster because populations of rockfish, lingcod, and other bottom dwellers dipped dangerously low — "woke me up to conservation," he says. The guys he once fished with saw his epiphany as a defection. He's been called a "sell-out" and worse on the streets of Gold Beach where he lives. But he doesn't think the maw between them and him is impossibly wide. "I think most fishermen want to take care of the resource," he says. "Most of them are conservationists in some shape or form."

That's what OSU social scientists Flaxen Conway and Bryan Tilt found last year. They, along with Port Orford resident Leesa Cobb, surveyed residents for an Oregon Sea Grant study.

"The perceptions of people (in Port Orford) have changed," wrote Conway and graduate student Christina Package in their 2010 report, *Longform Fishing Community Profile*. "In the past, people wanted to catch everything, but today they want to maintain a balance as far as catching and preserving the resource." The researchers interviewed one fisherman who had returned a 100-year-old yelloweye rockfish to the sea so that it could go on spawning. "You just can't kill everything you catch and catch as many as you want," he explained.

Jennings, too, voices the sustainability mindset. "We're really all on the same page here on this planet," he says. Even as he vents the fishermen's skepticism about marine reserves, he gets the scientific rationale behind them. "The positive effect that we're looking for — that we've been sold on — is that you'll get a spillover effect of more fish to catch in the future by giving up territory that we fish right now. We just want to make sure we get something back for what we're giving up."

To make sure Redfish Rocks yields data useful to both fishermen and scientists, Jennings has lent not only his voice but also his boat. Calvanese chartered *My Girl* and its captain and crew to help conduct hydrophone range testing. Other members of the Port Orford fleet have aided the research effort, as well, lending their time, their vessels (such the Leesa and Darrell Cobb's *Eagle III*, which Calvanese used to deploy the hydrophones around the reef's perimeter) and their expertise.

At the meeting's end, Jennings apologizes to the team for letting his emotions spill all over the meeting room. Hey, no problem, they tell him. Honest dialogue is, after all, the whole point of the team process.

Part of the Port Orford fleet, Eagle III has participated in scientific research with scientists from OSU (Photo: Heath Korvola).

Carnal Instinct

On the bright blue morning following the October meeting, gulls wheel and screech above the bay. Redfish Rocks shimmers just offshore. Jennings sits on the dock and tries to explain the wariness with which fishermen and scientists often regard one another. Their different modes of understanding the ocean — academic versus experiential ways of knowing — can put them at odds. Fishermen like Jennings tend to scorn insights gleaned from labs and laptops. He complains that scientists too often fail to respect the hard-won, hands-on learning that happens during many seasons at sea.

"We're out there on a daily basis," says the skipper, who started fishing commercially as a 9-year-old kid supplying the aquarium trade in Hawaii. "As a fisherman, you're readin' the birds, you're readin' the depth meter, you're seein' the bait fish, you're watchin' everything, because to be a fisherman you have to kinda revert back to that carnal instinct of bein' a hunter. And a hunter has to gather information just like a scientist does in order to quarry his prey. He has to take everything into consideration — the whole environment, the whole ecosystem. What's going on with the upwelling? Where's the temperature change? Where's the action? We're right in the middle of where there's whales feeding and birds taking off and sea lions workin'. We get to see the active part of nature on a daily basis."

Fisherman Blane Steinmetz, president of the Port Orford Fishing Marketing Association, puts it this way: "When we go to work out there, the scenery is a big part of it. Our 'traffic' is to watch the whales and the dolphins, not some stoplight on some asphalt. We see it, we live it, we breathe it. We are more concerned about overfishing than most people are. We want to keep this a sustainable fishery — fish smarter, not harder."

Researcher Profiles

TOM CALVANESE
M.S. graduate student
Marine Resource Management

SCOTT HEPPELL
Assistant Professor
Department of Fisheries and Wildlife

(Photos: Justin Smith)

The rancor rang out loud and clear in 2008 at a series of forums moderated by marine extension agent Ginny Goblirsch of Oregon Sea Grant. OSU researcher Selina Heppell was on hand to explain the science of marine reserves. Fishermen from Astoria to Brookings vented their anger and frustration at the meetings, which were convened by OPAC to engage coastal communities in discussions about a network of marine reserves proposed by Gov. Ted Kulongoski. Words and phrases like "suspicion," "tough sell," "mistrust," "fracas," and "overwhelming opposition" peppered the news coverage of the forums. The biggest concern expressed by fishermen was a fear that scientists and conservationists involved in the marine reserve effort were harboring "hidden agendas," according to Goblirsch. Ultimately, the "listening and learning" forums revealed an acute need for more dialog and led to the creation of community teams like the one at Port Orford.

But Port Orford was already well ahead of the curve. Fishermen and local leaders had gotten out in front of the issue several years earlier, forming a group called the Port Orford Ocean Resources Team (POORT) to study and discuss a raft of issues, including marine reserves. Leesa Cobb — who took the helm of POORT from founding director and OSU alum Laura Anderson after Anderson opened a restaurant and fish market in Newport called Local Ocean Seafoods — says the action was a way for the community to take charge of its own destiny.

"Marine reserves have been on the radar for ocean management worldwide for years," Cobb says. "It wasn't something we tried to avoid. We didn't try to run from it, we didn't try to hide from it. We said, 'It's out there; let's talk about it.'"

Fisherman and team member Aaron Longton explains it this way: "We figured marine reserves were inevitable. It was either engage with and shape this thing so it works for us or have it done to us, kicking and screaming. That didn't make any sense."

And so this forward-leaning band of Port Orfordians nominated Redfish Rocks just off their shores as Oregon's first pilot reserve. Says Blane Steinmetz: "We've given up Redfish Rocks so, hopefully, the research will be done on it. We want to help with the research. We know these grounds. We've fished on 'em. We know where the fish are." To further engage the broader community, Calvanese has launched a website called Fishtracker at www.fishtracker.org where people can read about his work and even adopt a fish to help raise funds to support his rockfish tagging research. His "Adopt-A-Fish" program was created in partnership with the Redfish Rocks community team.

Struggling for Consensus

As the morning sun warms Jennings' back, he looks toward the reef whose six basaltic pinnacles ("emergent rocks" as the scientists call them) break through the cobalt surface of the sea.

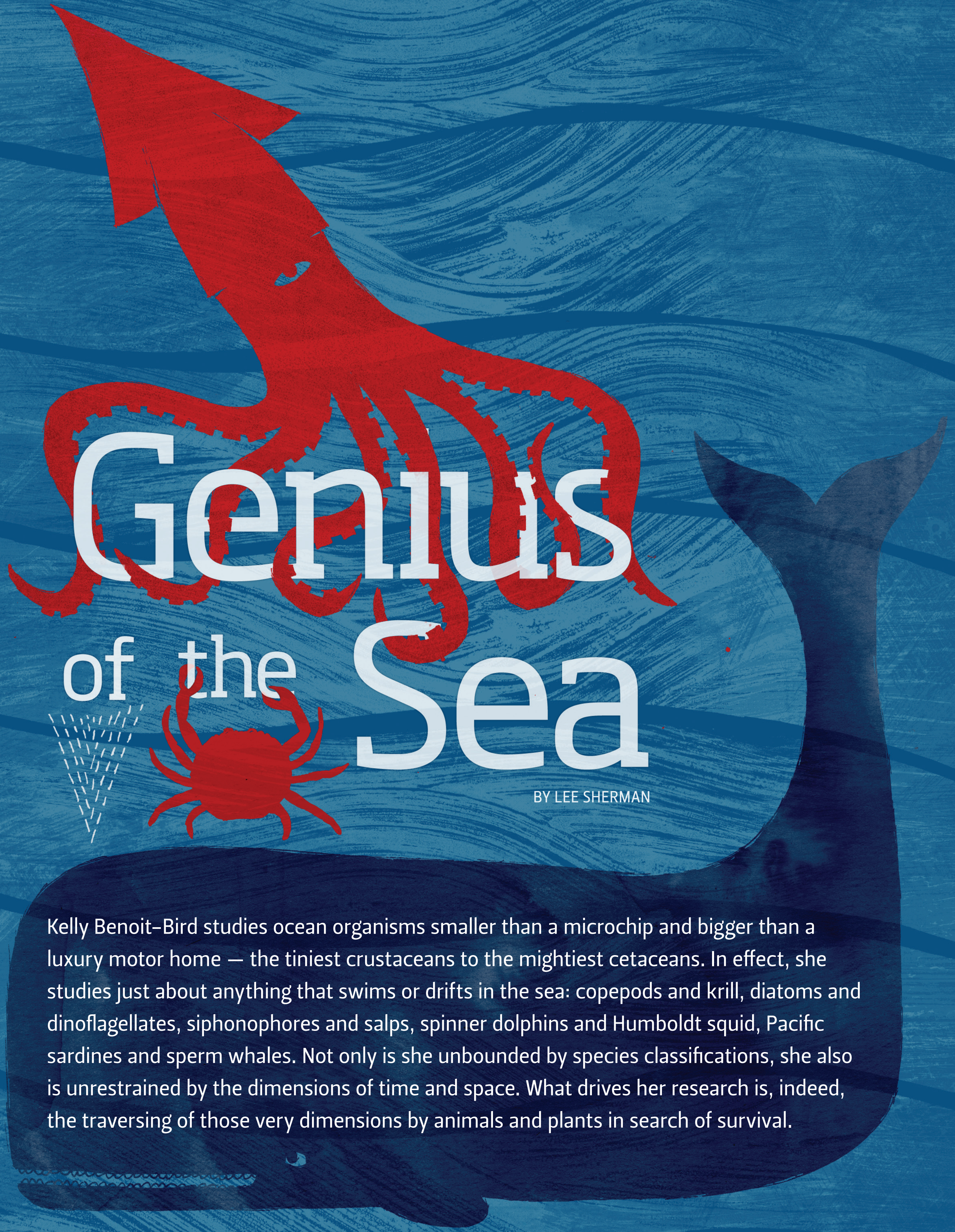
"I think it's very easy to criminalize the fisherman," he says. "It always comes down to 'us and them.'" He wonders why a "warm-and-fuzzy" meeting of the minds — "you know, rainbows and everybody lovin' each other" — is so elusive.

For her part, Leesa Cobb sees more harmony, more unity of intent, among Port Orford's fishermen and the scientists who study their ocean. "Our community has been working with scientists for years, and we learn from each project something new about our area," she says. "Do we need to learn about our fishing region? Absolutely, if we want sustainable fisheries."

Still, resentments continue to simmer even as the team-crafted proposals for a network of five Oregon marine reserves move forward. Approved by OPAC in December, the plans are headed for legislative action and, ultimately, implementation and enforcement. Fishermen harbor ongoing doubts that shrinking fishing grounds now will boost their catches down the road. Scientists like Hixon, on the other hand, question the true biological value of the two pilot reserves that were whittled down in size during months of negotiations — reserves that he characterizes as "dinky."

Still, Hixon sees hope in the Cape Perpetua process he helped lead, a process that has resulted in a proposal both sides can live with. "I was heartened by the fact that the majority of the members on our community team were open-minded, respectful, learned from each other, listened to each other, struggled to find a compromise and to reach consensus," he says. "And we did." terra

Port Orford fisherman Scott Hill unloads the day's bounty of sablefish – also called black cod by local fishermen (Photo: Heath Korvola).



Genius of the Sea

BY LEE SHERMAN

Kelly Benoit-Bird studies ocean organisms smaller than a microchip and bigger than a luxury motor home — the tiniest crustaceans to the mightiest cetaceans. In effect, she studies just about anything that swims or drifts in the sea: copepods and krill, diatoms and dinoflagellates, siphonophores and salps, spinner dolphins and Humboldt squid, Pacific sardines and sperm whales. Not only is she unbounded by species classifications, she also is unrestrained by the dimensions of time and space. What drives her research is, indeed, the traversing of those very dimensions by animals and plants in search of survival.

AS A PELAGIC (OPEN OCEAN) ECOLOGIST, Benoit-Bird investigates the intricate interactions among predators and prey that take place day and night, full moon to new moon, summer to winter, El Niño to La Niña in Earth's vast oceans.

"Despite the apparent variety of the ongoing research projects in my lab, all of our research aims to understand the role of spatial and temporal patterns in ecological processes on spatial scales ranging from sub-meter to hundreds of kilometers, at temporal scales of minutes to years, and over a range of animal size from zooplankton to great whales," Benoit-Bird explains on her webpage for Oregon State University's College of Oceanic and Atmospheric Sciences.

The challenge is almost beyond imagining. Within the world's 326 million cubic miles of seawater, most species interactions happen where humans cannot witness them. Besides, as Benoit-Bird points out, the marine environment is in constant motion. On land, plants hold fast to the ground. Forests may be complex ecosystems to study, but at least they stay put. At sea, plants drift on tides and currents, rising and falling in the water column with the sun and the moon and the seasons.

"In the ocean, plants are incredibly small, have very little structure and move all over the place — sometimes even actively," the researcher says. "Some of the plants can swim."

To compensate, Benoit-Bird extends her senses. She devises novel acoustic and optical technologies that collect data remotely, giving scientists a virtual front-row seat on some of nature's most mysterious processes. Her innovations are opening the world's oceans to human understanding in ways never before possible. In 2010, the John D. and Catherine T. MacArthur Foundation recognized her pioneering work with a prestigious $500,000 MacArthur Fellowship — popularly known as a "Genius Award."

Life in Layers

Instead of being like a big pot of soup with its ingredients evenly mixed, the ocean is more like a big blue torte with dense congregations of organisms layered vertically, Benoit-Bird and other oceanographers have learned in recent years. In coastal waters across the planet, scientists have discovered that plankton, both in its plant and animal forms, coalesce into layers two or three feet thick, sometimes extending for miles horizontally. These "thin layers" of tiny life forms — which Benoit-Bird calls "great smorgasbords of food" — likely hold critical clues to how ocean ecosystems work.

"While thin layers are just beginning to be investigated," Benoit-Bird writes in a recent issue of *Continental Shelf Research*, "thin layers are likely to be important for a variety of biological processes, including growth rates, reproductive success, grazing, predator-prey encounters, nutrient uptake and cycling rates, as well as toxin production."

To get inside those mysteries from the deck of a research vessel, Benoit-Bird has been developing a whole new generation of tools. She uses sonar technologies to collect acoustical data that are then fed into computers for analysis. To broaden their options, she and her collaborators have experimented with linking disparate gear types, such as video cameras and echosounders (devices that locate layers and schools of organisms by sending out pulses of sound waves). They've designed new uses for old standbys, like retrofitting a remotely operated vehicle ("a little tethered robot") to find and track plankton layers by following water density. They've invented a new kind of sonar to study the distribution of individual zooplankton inside thin layers.

Her ambitious research goals, supported by the National Science Foundation and other agencies, necessarily push her toward more expansive technologies.

Kelly Benoit-Bird (Photo by Craig Mitchelldyer/Getty Images/for MacArthur Foundation)

"My perspective is that we shouldn't be limited by the tools we have," she says. "I like to think about the question first and figure out how to address it later. It may mean we have to develop a new tool or a new way of analyzing data or a new way of deploying instruments to get at the questions we're interested in."

A "Spatial Ballet"

Computer animations created from recent acoustical studies show fish diving through plankton layers, gobbling holes in the tightly packed, food-rich patches. Another animation shows spinner dolphins swimming in tight formation to corral layers of lanternfish during cooperative feeding.

"The emerging picture is one of an incalculably complex, finely tuned, and delicate interaction between predators and prey, chemistry and light, currents and water column, night and day," writes author Julia Whitty in a recent *Mother Jones* article featuring Benoit-Bird. "Some semblance of this spatial ballet, played in weightless three-dimensional darkness, has likely been part of the oceans since the oceans were brought to life: layers of life gathering in extremely high densities to feed or to avoid being eaten." terra

ON THE WEB: At *oregonstate.edu/terra*, see Benoit-Bird's animations, including one of cooperative hunting by dolphins.

From Research to Retail

Gil Sylvia tackles issues by sharing information and developing trust

Partnering with coastal communities in support of Oregon's vital seafood industry brings OSU Professor Gil Sylvia in close contact with fishermen and other local stakeholders. (Photo: Don Frank)

Gilbert "Gil" Sylvia spent childhood summers riding a bus through the lake-studded military base where he lived, hauling buckets of live fish from pond to pond. He and his buddies were trying to alter the balance of species for one reason: to boost their own catches. They never guessed that by dumping sunfish, bass and catfish into the Army's carefully managed trout ponds, they were making a mess of fisheries management. The clean-up cost thousands, he learned later.

"I'm still trying to make up for it," laughs Sylvia, a professor of Agricultural and Resource Economics at Oregon State University.

Today, he has decades of experience in science and economics to back up his efforts. As superintendent of OSU's Coastal Oregon Marine Experiment Station (COMES) — the largest such station in the United States — Sylvia oversees research and outreach in ocean resource science, management, policy and marketing. Along with 20 faculty and staff members and several dozen graduate students located at the Hatfield Marine Science Center and the Astoria Seafood Laboratory, his collaborators include the Oregon seafood commodity commissions (salmon, crab, trawl and albacore tuna), the Community Seafood Initiative and various industry groups, as well as state and federal agencies. COMES researchers focus on topics from aquaculture to marine mammals, marketing and economics. According to OSU's Oregon Invests database, COMES programs generated more than $12 million in economic impacts in 2008 and 2009 and produced an equivalent of 30 to 40 new jobs for Oregon and Pacific Northwest coastal communities.

Terra writer Lee Sherman interviewed Sylvia in his Newport office to get an overview of COMES and its impact on Oregon coastal economies and communities.

TERRA: What's the key to bringing the university and the fishing community together?

SYLVIA: The key is trust. They have to trust you to be honest and objective, not to have agendas.

TERRA: How do you develop that trust?

SYLVIA: We create a table for scientific discussion and ideas, get people to talk about those ideas, brainstorm them, and put teams together that aren't just traditional scientists — teams that include members of the community, the industry — to tackle the problem or seize the opportunity. I don't think it's well understood just how tough our fishery laws are, how many challenging goals have been set into law, particularly over the last decade, for managing and conserving every single stock of fish. For example, at any given time there may be 50 salmon stocks found off the Oregon coast. There are at least 60 stocks in the ground-fish fishery. So you are managing hundreds of species and stocks. Each one has to be conserved at a level equal to or above a stock level that maximizes biological yield. Without really good science, we won't be able to do it successfully because the challenges are so difficult. You have to bring everyone to the table to figure this out.

TERRA: Did we learn things during the spotted owl wars in the '80s that are helping inform the current discussion about marine reserves?

SYLVIA: Clearly, the terrestrial wars — in terms of using space, creating corridors and linkages, and conserving biodiversity on the landscape — are having a great deal of influence on thinking about the design of the reserves. The linkages may not be exactly the same because you're dealing with a three-dimensional environment in the ocean. But the idea is that one area may be a good spawning ground, another area may be the settlement ground. You're trying to accommodate the different life histories and connect them spatially. We're moving through a new era of spatial management in the oceans. Thirty years ago the fishing industry could go just about wherever they wanted to go, fish where they wanted to go. Today, if I drew you a fishing map of the ocean and showed you all the rules about spatial use, just for fishing, you'd have a hard time reading the map. Now you've got marine reserves, wave energy, wind energy. And so you have traditional uses clashing with new uses just like in the terrestrial landscape. In some ways it's not that different.

TERRA: Aquaculture is another potential user of ocean space.

SYLVIA: Yes, but not at the same rate. That's because offshore aquaculture is really quite difficult to do, particularly in our dynamic environment on the West Coast. But we're just about at the limits of what we can generate from ocean resources. The world, collectively, might be able to produce another 30 percent with really smart management of fishing resources. But it's still going to be capped by the natural productivity of the oceans. So the only way to get more seafood is from aquaculture. But how do you accommodate aquaculture, given concerns about space, disease transfer or effluent? All those things have to be considered and thought about to accommodate it in smart ways.

TERRA: What was OSU's stance?

SYLVIA: The leadership right here at the Marine Experiment Station, Chris Langdon in particular, pulled together an offshore aquaculture conference to try to get an honest discussion going about all the views and to bring experts from around the United States to the table. We had about 130 people participate right here at the Hatfield Marine Science Center. It was an excellent conference. We had offshore aquaculturists, many of whom are former commercial fishermen, talking face-to-face with Oregon fishermen. My own view is, if you want to build on your fishery industry, your seafood industry, you have to consider aquaculture. But you also have to think about impacts. "Zero impacts" is a big value today. But you can't use the ocean without some impact. The question is, what's the standard? Is it zero impacts or reasonable impacts? What are reasonable tradeoffs between the different uses in the ocean? How do we measure those impacts and tradeoffs? At what point do they become damaging? I think the university has a very big job in leading those debates and bringing people to the table, having an open, honest conversation, hitting all the issues and searching for solutions.

TERRA: Pacific whiting was your first big success as superintendent.

SYLVIA: I hadn't been here more than a week when a fisherman came up to me and said, "Oh, you're that new guy that was hired by the university." We started talking, had a couple of beers. And then he goes: "You know, I've got to tell you something. You're here for one reason and one reason only: whiting." And I said, "What's a whiting?" I spent the next 10, 12 years of my life on it. Probably half of my work was just Pacific whiting, every part of it, from quality to marketing to bioeconomic modeling. It's now Oregon's largest fishery, by volume. It's used to make a variety of seafood products, including surimi — a fish product that can mimic crab legs or other seafood products. In fact, one of our faculty, Jae Park, is an international leader in surimi research and education. That is exactly the kind of project we can conduct in Oregon, with industry, state and university partners all together at the table: intelligent discussions, smart approaches and, well, here we are. terra

ON THE WEB: Read the full interview with Gil Sylvia at *oregonstate.edu/terra*

Waves slam a mock-up of Seaside in this experiment at Oregon State University's Hinsdale Wave Lab (Photo: Frank Miller)

Uncharted Waters

Communities, engineers and scientists prepare for the next tsunami

By David Stauth

It may come like it did the last time, in the middle of a cold and blustery January night. Suddenly the ground will begin to shake, windows will shatter, bridges collapse, the electricity will go out and parents will frantically try to find a flashlight and dig sleepy kids out of bed, ignore everything else and run — because they know they only have minutes before the water arrives.

Even worse, it may come on a warm and breezy summer afternoon in July, when tens of thousands of visitors fly kites, build sand castles and play fetch with their dogs on one of the most beautiful stretches of coastline in the world. The rumble and shaking on the crowded beaches will quickly be replaced by a receding shoreline as the water eerily slides away, and people will start to run, anywhere they can, to get to higher ground — because they know the water will soon be coming back.

It will be scary, it will be destructive, and it's going to happen, reasonably soon. Pat Corcoran, a coastal hazards outreach specialist with Oregon Sea Grant, is mindful of these risks and calls the disaster that's waiting to happen "arguably the greatest recurring natural hazard in the lowest 48 states." That's about right. Subduction zones — like the Cascadia Subduction Zone that lurks just off the coast of the Pacific Northwest — produce the most massive earthquakes in the world. And their "up and down" ground motion triggers tsunamis, one of the most deadly waves in the world.

Like Clockwork

The problem is, at least in the United States, these events don't happen very often. In fact, until the mid-1980s, scientists didn't think great earthquakes and tsunamis were caused by Pacific Northwest fault zones. Then some pioneering research by the U.S. Geological Survey, Oregon State University and others began to unravel some ancient mysteries. Scientists found that not only do they happen here,

In Brief

THE ISSUE Along the Pacific Northwest coast, earthquakes and tsunamis are a fact of life. Geologists have documented their past behavior, and we're overdue for another. Coastal communities are likely to be hit with devastating loss of life and destruction of critical buildings and utilities.

OSU LEADERSHIP Engineers and scientists are working with the coastal communities of Cannon Beach and Seaside and state and federal agencies to understand the likelihood of a Cascadia Subduction Zone earthquake and tsunami. By testing wave forces, structures and evacuation options, they are leading efforts to prepare for the disaster that will inevitably strike the region.

they occur pretty regularly, about every 300 to 500 years on one part or all of the Cascadia Subduction Zone, which runs 700 miles from Cape Mendocino in California to Vancouver Island in Canada. The last event was pinpointed because the enormous tsunami it created raced all the way across the Pacific Ocean to Japan, where written records were kept. It occurred here about 9 p.m. on January 26, 1700.

The newest studies produced by Chris Goldfinger, an OSU marine geologist and one of the world's leading experts on the Cascadia Subduction Zone, indicate that there's a 37 percent chance of a partial rupture of the zone within the next 50 years, an event that could be similar in magnitude to the 2010 earthquake in Chile.

> "We're going to get hit worse than Chile did; I suspect much worse. We have many large buildings in our cities that were built in the '50s, '60s and '70s that will not do well in the earthquake."
>
> — SCOTT ASHFORD, SCHOOL OF CIVIL AND CONSTRUCTION ENGINEERING

"Perhaps more striking than the probability numbers is that we have already gone longer without an earthquake than 75 percent of the known times between earthquakes in the last 10,000 years," Goldfinger says. "And 50 years from now, that number will rise to 85 percent."

But Are We Prepared?

A few years ago, residents of Cannon Beach were pondering that question, as they followed the developing science on subduction zone earthquakes and worked with officials from the Oregon Department of Geology and Mineral Industries on evacuation maps for the anticipated tsunami.

Preparation for a tsunami, in this context, would be defined as people knowing what to do, where to go, getting to high ground and having the time to do it. Jay Raskin, a longtime resident, community leader and local architect, didn't like what he was hearing.

"Around then, the scientists were describing and updating the potential risks for an earthquake and tsunami caused by the Cascadia Subduction Zone," Raskin says. "We talked about the distances we needed to go, how high the water might get, where high enough ground was, the bridges that probably would be destroyed.

"And then we're thinking, 'Oh darn, this strategy of getting to high ground might not work for everyone,'" he says. "For some people there just might not be enough time. We needed another option."

A Sunny Day at the Beach

Cannon Beach is butted up against coastal headlands and stretches for several lovely miles along the Pacific Ocean coast. Most of its 1,700 residents live within a few blocks of the beach, and about half of them, and 75 percent of the businesses, reside within a tsunami inundation zone. But it could be much worse. On a peak summer day, up to 12,000 people may crowd the beaches around Cannon Beach. The city presents a microcosm of an issue that affects a vulnerable shoreline about 900 miles long.

In addition to a tsunami response plan, the city needed a new city hall. So Raskin and others had an idea. Why not build a structure that could survive a tsunami, stand above the incoming water, give local residents and visitors a safe place they could run to on short notice, save many lives, and also serve as a base of operations after the disaster to help the city recover and get back up and running?

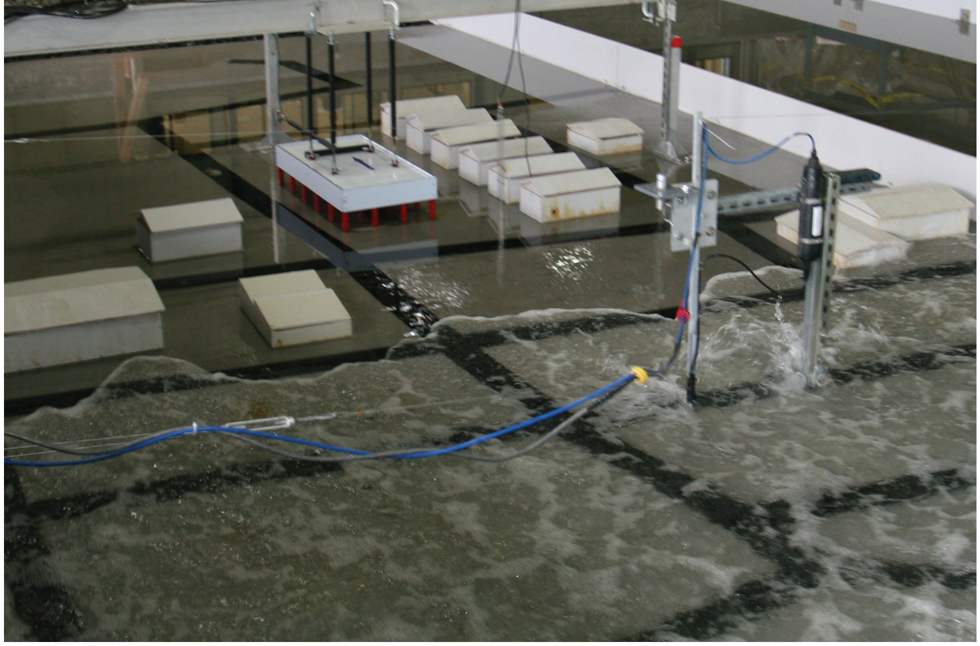
It was the comparatively new concept of "vertical evacuation." Two problems: No structure of that type had ever been built in the United States, and in the few places where such structures had been built, such as Japan, none had yet experienced a tsunami. So as an engineering challenge, this was literally uncharted water. Also, it would cost more. A design was created for a new 10,000-square-foot structure, and it's estimated to cost around $4 million, about double the cost for a more conventional building.

But the issues are real, and the Cannon Beach residents knew it. They had watched the devastation from the Sumatra earthquake and tsunami in 2004, where 230,000 people died, most of them not from the earthquake, but rather the tsunami. The geology of that region is nearly identical to the Cascadia Subduction Zone.

The Real Enemies: Time and Transportation

So last May, at OSU's Hinsdale Wave Research Laboratory, a small model of the proposed new city hall building at Cannon Beach was being hit by simulated tsunamis repeatedly. It wasn't fancy, essentially a square structure on stilts, but very strong and with a sturdy foundation. But how strong is strong enough? What will be the effect of debris, such as floating cars, slamming into the pillars? OSU was helping Cannon Beach to answer those questions, in research supported by the National Science Foundation.

"We have to know just how strong this building has to be, so the community can build something that will work, but at the same time keep costs as low as possible," says Dan Cox, an OSU professor of coastal and ocean engineering.



OSU's Hinsdale Wave Laboratory includes one of the world's largest tsunami test facilities. Here, simulated waves hit the proposed Cannon Beach evacuation shelter and city hall. (Photo: Seth Tomas)

"In engineering, this is new territory. We're just scratching the surface of everything we need to know, but these studies should give us a higher degree of confidence in what we build, and in the process our students are learning how to build structures of this type for the future."

Other work to aid Cannon Beach is also under way at OSU. Harry Yeh, the Edwards Professor of Coastal and Ocean Engineering, one of the world's leading experts on tsunamis, has worked with the community for years to help it address concerns and design the new structure. He is now working on an evacuation plan.

"We know we can build a structure that will survive an earthquake and tsunami, and could serve as an emergency shelter," Yeh says. "Strong, reinforced concrete buildings can stand up to that, we saw that in Indonesia in 2004. But it will cost more, so to make this feasible, we have to figure out the best way to balance cost and function."

But Cannon Beach is one small town, on one short section of beach. The earthquake on the Cascadia Subduction Zone, when it happens, could affect three states, some of British Columbia, major cities and millions of people.

Living in the Quake Zone

OSU researchers are doing what they can. Earthquake and tsunami simulation modeling is being done in several Oregon sites. A course is being taught on "living with earthquakes." Scientists have gone to Sumatra, to American Samoa, to Chile, to the sites of all the recent major subduction zone earthquakes and tsunamis in recent years to learn whatever might help.

To further explore these questions, OSU engineer Scott Ashford visited Chile after the February 2010 magnitude 8.8 earthquake, also on a subduction zone similar to Cascadia. The professor and head of the School of Civil and Construction Engineering was part of a team of experts supported by the NSF, who wanted to learn as much as possible about what had happened to bridges, buildings and other structures.

"Part of what was striking about the Chile earthquake was the geographic extent of the damage. It was spread out over an area essentially from Seattle to Medford here in the U.S., and from I-5 to the coast," Ashford says. "The damage itself, as you often see with earthquakes, was variable. Some areas were very hard hit, others much less."

"In Concepción, all the bridges from the south were collapsed or out of commission; people were cut off," Ashford says. "You would see people living in tents, staring at the building they used to live in but afraid to enter it even for a few minutes to get their belongings, fearing it would collapse. And of course in the areas hit by the tsunami, the damage was just devastating; it was really heartbreaking."

Engineer for Resilience

Oregon and Washington, Ashford says, face even greater devastation in the future. "We're going to get hit worse than Chile did; I suspect much worse. We have many large buildings in our cities that were built in the '50s, '60s and '70s that will not do well in the earthquake."

A prime lesson Ashford says he took away from the recent Chilean experience is to preserve the lifelines: electricity, gas, water, communication and transportation, as well as critical facilities like hospitals, fire stations and schools.

"What we need here is resiliency, to provide the infrastructure for rescue, relief, and recovery efforts that will enable Oregon to bounce back from such a disaster," Ashford says. "Like the proposed city hall at Cannon Beach, that will save lives and give you something to build around."

Ashford sees OSU as the logical institution to lead that effort. Working with the Oregon Department of Transportation, the National Oceanic and Atmospheric Administration, utility companies, cities, and other agencies, OSU has the engineering and scientific and management expertise to help coordinate preparation for a major disaster, to build in that resilience.

But there's a lot to do and only a limited time available to do it. Because a massive earthquake is coming, and a massive tsunami will sweep ashore with deadly force. They are coming. We know that.

Are we prepared?

No. terra

Planet Plankton

BY NICK HOUTMAN

The color of the ocean can range from steel gray to green or sky blue, but during a research cruise off the coast of Chile on board the R/V (research vessel) Melville in December, Angelicque White saw something unusual. "We were sitting on the bow of the boat watching the whales go by. One whale, two whales, 10 whales — it was amazing," she says in a video from the ship. "And suddenly we realized we were in this red sea. You can see these strands, these filaments of bright, bright red. It's gorgeous."

Scientists ran up on the deck to lower fine-mesh nets into the water, hoping to catch a few of the organisms responsible for this colorful display, but their efforts were in vain. Their tiny quarry slipped right through the nets. Finally, using that most sophisticated of oceanographic instruments, the plastic bucket, they brought up a water sample and put a drop under a microscope. According to White, what they saw was as puzzling as it was exciting. "We saw these tiny . . . maybe dinoflagellates (plankton associated with "red tides"). They're motile; they've got flagella. And these things are just zooming around," says White. Other experts suspected the organisms were ciliates, which are common in the Pacific Ocean plume from the Columbia River (positive identification — and a $20 scientific bet — will be settled by genomic analysis). Their difficulty in identifying the organisms is testimony to the huge microbial diversity of the oceans.

It was another day at sea for Oregon State University oceanographers Ricardo Letelier, Joe Jennings Jr. and White. They had joined colleagues from Chile, Spain, Woods Hole, MIT, UC-Santa Cruz and the University of Hawai'i at Manoa on a 2,300-mile research expedition from the rich fishing grounds off Chile to one of the world's least productive seas, located around Easter Island. Their purpose: to understand how microbial diversity changes from areas of high to low productivity. As scientists in OSU's College of Oceanic and Atmospheric Sciences and members of C-MORE — the Center for Microbial Oceanography:

Research and Education — they are studying the under-appreciated but most abundant life forms on the planet. C-MORE is one of 17 Science and Technology Centers funded by the National Science Foundation.

Every Breath We Take

To appreciate their mission, it helps to know a little about ocean microbes. They help to control the chemistry of the atmosphere by producing and recycling carbon dioxide and other greenhouse gases. And those that conduct photosynthesis — the phytoplankton — supply much of the oxygen we breathe. In fact, some scientists suggest that we can thank one of the smallest and most abundant of them, *Prochlorococcus*, for every fifth breath we take. "These organisms are oxygenating the planet. They're the base of the food web. Yet we know very little about how shifts in microbial diversity and productivity impact ecosystem function," says White.

Better understanding won't come too soon. Last summer, a report in the journal *Nature* by a Dalhousie University research team in Nova Scotia concluded that phytoplankton have been declining in the world's open oceans at the rate of about 1 percent per year for the last century. While that study has generated debate in the scientific community, future declines are likely as the oceans warm. That's because as temperatures increase, the seas will separate more strongly into nutrient depleted surface and nutrient rich deep-ocean layers, reducing the nutrient upwelling that fertilizes plankton at the sunlit ocean surface.

Letelier agrees that warmer oceans will likely mean lower plankton productivity globally. However, he adds, it's not that simple. In some areas, production is increasing. For example, through nearly 20 years of intensive study at a research site known as Station ALOHA north of Hawaii, he and other researchers have found that plankton production has increased as the sea has become warmer and more acidic.

Nitrogen for Lunch

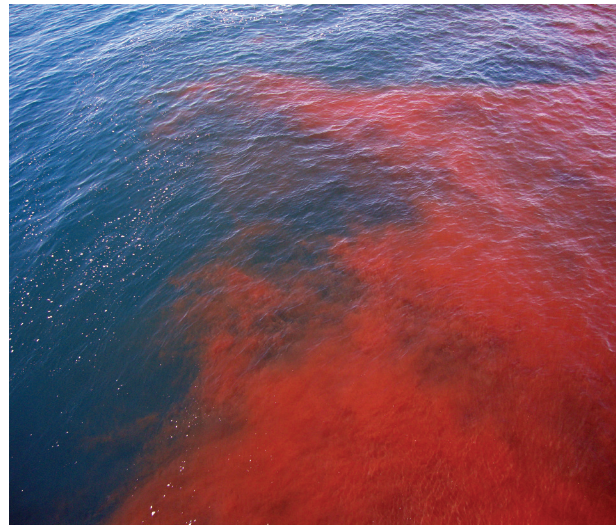
The reason for this apparent contradiction may lie in nitrogen, a critical nutrient for plankton growth and one that is in low supply in large areas of the oceans. Most plankton depend on nitrate (a molecule composed of nitrogen and oxygen) for their nitrogen supply. Experiments by Letelier, White and others have demonstrated that phytoplankton that use nitrogen gas diffused into the ocean from the air instead of nitrate can multiply even as other nutrients are in decline. On top of that, as more carbon dioxide enters the water from the air, these "nitrogen-fixing" microbes may grow faster until some other key nutrient becomes limiting.

It's also important to remember, says White, that ocean microbes have the ability to respond to changing ocean conditions. "The variability that organisms display in their expression of genes over the course of a day is huge. And scaling that capacity for adaptation up to the next 10 years, when the oceans may be more stratified, warmer, more carbon-rich, in order to try to project what microbes might do in that kind of system, is difficult."

The OSU researchers have developed new optical methods for monitoring plankton growth and abundance. And during cruises to Station ALOHA and in the South Pacific, they run shipboard experiments to see how microbial communities will respond to water that is warmer, more acidic or supplied with different forms and amounts of nutrients such as iron and phosphorus.

Depth Charge

They are also pioneering new ways of conducting experiments. In one 2008 study at Station ALOHA, they used the motion of ocean waves to pump water from 300 meters deep in the ocean to the surface. They wanted to see if a disturbance to the microbial ecosystem — in this case a sudden shot of nutrients from below — would stimulate plankton production.



An unexpected encounter with "red tide" plankton was a bonus for C-MORE researchers on the R/V Melville. (Photo: Angel White)

Unfortunately, the study ended prematurely. The pumps broke from the stress of ocean waves before the researchers could see an impact. "We know a lot about how upwelling works and the physics of the ocean," Letelier said after the study ended, "but there also are things we don't know, which is why this study is so important. In this open ocean area near Hawaii, for example, phytoplankton blooms occur in the summer when there are almost no nutrients at the surface and the winds generally are calm. What triggers the blooms and where are the nutrients coming from? We need to know." Lead researcher David M. Karl of the University of Hawaii is planning to repeat the effort, which was funded by the NSF and the Gordon and Betty Moore Foundation.

"It's about understanding the base of the food web that covers 70 percent of the planet," says White. terra

ON THE WEB: see videos from the South Pacific expedition at *cmore.soest.hawaii.edu/cruises/big_rapa/videos.htm*

Run Silent, Run Deep

OSU's growing fleet of underwater gliders monitor the Pacific Ocean

BY MARK FLOYD

For more than half a century, oceanographers have ventured out of Newport to measure, probe and monitor the Pacific Ocean off the central Oregon Coast. And since the 1950s, these seafaring researchers have recorded about 4,000 "profiles" of the near-shore waters — surface to bottom measurements of temperature, salinity and oxygen levels that begin to tell us how the world's largest ocean influences everything from our weather to fisheries.

Then in 2005, Oregon State University scientists tested a prototype undersea glider that could be programmed to patrol beneath the ocean surface and collect many of the same measurements. At the time, the scientists predicted that these gliders could revolutionize the study of the world's oceans.

Their vision is rapidly becoming a reality.

In the past five years, a fleet of gliders operated by OSU's College of Oceanic and Atmospheric Sciences has covered more than 43,000 kilometers, a distance that would more than circumnavigate the globe. Even more striking is the productivity of the sleek, torpedo-like machines. In those five years, the gliders have recorded more than 156,000 oceanic profiles, almost 40 times what six decades of shipboard studies have provided.

"That's pretty amazing, when you think about it," says Jack Barth, a professor of oceanography and one of OSU's glider pioneers. "Each year alone, we log more profiles than have ever been recorded via ship off Newport. And the beauty of gliders is that the data is continual. They record 24 hours a day, regardless of the weather or how rough the sea is."

Underwater vehicles are not new to research, but the autonomous gliders used by OSU differ from earlier versions because they lack tethers or propellers — meaning they don't have to be accompanied by a ship. The gliders instead are driven by buoyancy changes, which lessen the overall energy consumption. By displacing seawater, the gliders increase their volume and become more buoyant. Or they can decrease their volume and become heavier, sinking lower in the water. Small wings on the gliders translate some of that vertical motion into forward motion.

The machines can be programmed to run for three to five weeks, from near-shore to the continental slope, and every six hours they rise to the surface and transmit data to OSU computers via satellite. The data they collect informs scientists on conditions including El Niño and La Niña, hypoxia (low oxygen) and resulting "dead zones" and harmful algal blooms.

Expanding the Fleet

Barth and fellow OSU oceanographer Kipp Shearman, together with their team of faculty research assistants and graduate students, operate a fleet of nine gliders. Six are Slocum gliders, manufactured by Teledyne Webb Research of Falmouth, Massachusetts, and based on the original prototype tested in 2005. Three are new Seagliders developed at the University of Washington. The Slocums can go as deep as 200 meters below the surface; the newer Seagliders can explore the ocean down to 1,000 meters and stay out for months.

Each glider costs between \$100,000 and \$200,000, so the OSU fleet is an impressive resource that is about to get much better.

> "In the past five years, a fleet of gliders operated by OSU's College of Oceanic and Atmospheric Sciences has covered more than 43,000 kilometers, a distance that would more than circumnavigate the globe."

Three years ago, OSU was selected as one of the lead institutions for the \$387 million Ocean Observatories Initiative, a National Science Foundation-funded project to study the world's oceans and their relationship to climate variability. One component of that project is to create a coastal observatory off the Northwest coast that will use moorings, buoys and gliders to better observe and monitor the ocean.

While engineers are still designing the hardware and instrumentation for the moorings, OSU in 2012 will deploy six new gliders — plus an additional half-dozen gliders on shore to be rotated into the observation array — bringing the total fleet to 21. And the new gliders will include instrumentation that has piqued the interest of ecologists, the fishing industry and others.

"In addition to the core instrumentation, these new gliders will be able to use acoustics to measure water velocity," Barth adds. "For the first time, we will be able to nearly simultaneously map ocean currents – from the surface to the bottom of the ocean – and detect just where these underwater 'rivers' run."

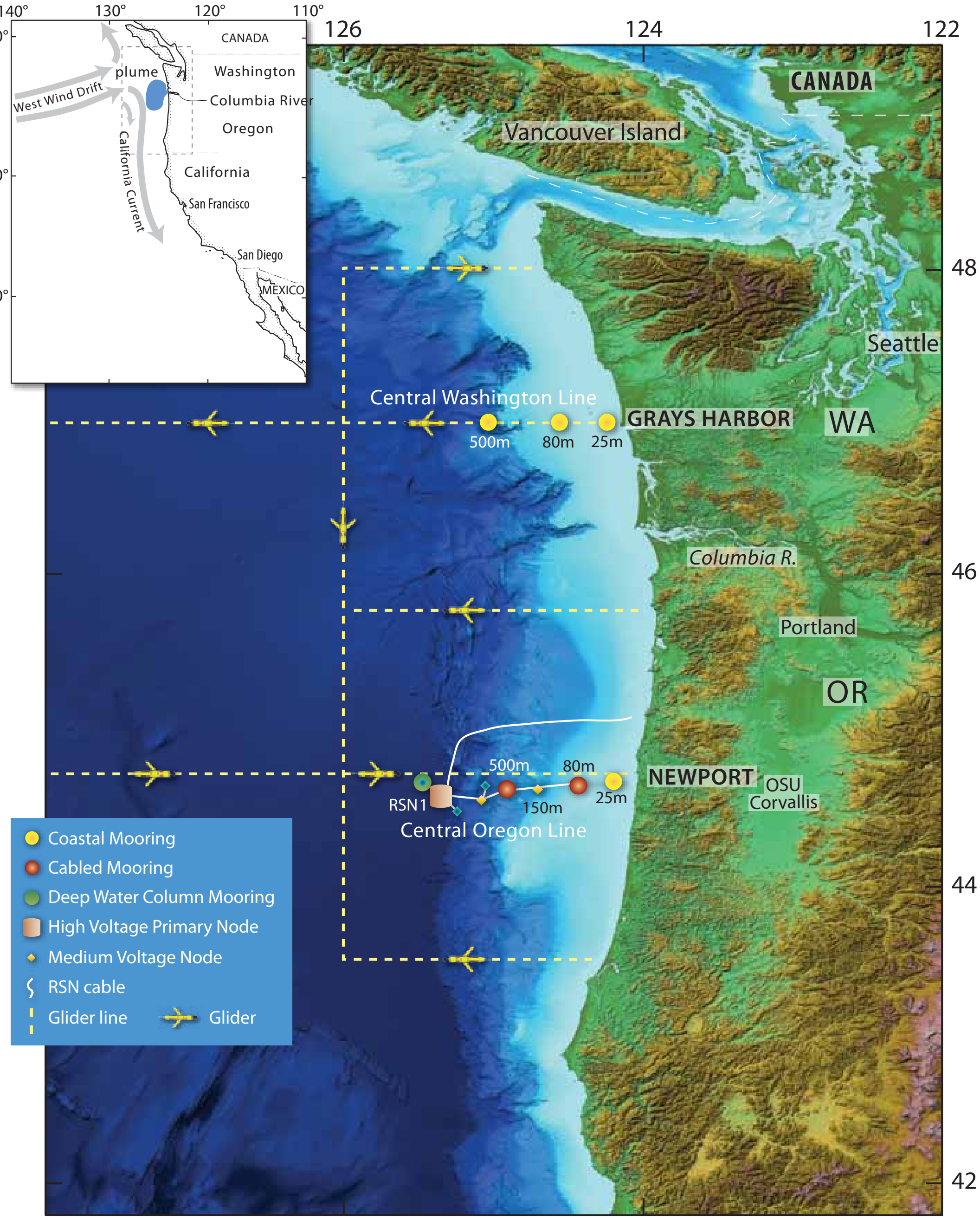
Public Access to Data

Data from the Ocean Observatories Initiative will be available as they are being collected and shared with researchers and the public alike.

"The fishermen we've talked to are intensely interested in the data we will generate," he says. "Crabbers don't want to put their pots into areas that have strong bottom currents, nor do trawlers want to contend with strong drifts. The findings will also be important for ecologists studying larval dispersal of marine animals."

Technology is advancing so rapidly, Barth says, that the gliders will carry new instruments as early as the next year or two. "We're putting hydrophones onto the moorings, for example, and there's no reason why we can't put them onto the gliders and listen for marine mammals or fish that have been tagged with transmitters."

OSU's fleet of 21 gliders will enable Barth, Shearman, scientific colleagues and the public to continually monitor five east-west transects — off the northwest tip of Washington, Gray's Harbor, Cape Mears, Newport, and Coos Bay — while rotating the machines for calibration, maintenance and battery charging. The newest gliders will allow them to run a north-south pattern about 150 kilometers off the coast and, with separate NOAA funding, begin a new east-west transect off Crescent City, California.



"We've been doing the Newport sector for five years now," Barth says, "and we've seen things we've never seen before, from the influence of coastal rivers, to details about hypoxia. It's become one of the most well-studied ocean regions on Earth. Now we'll be able to get similar coverage up and down the coast, from the California border to Vancouver Island.

"It will be," he added, "revolutionary." terra

This map of the Endurance Array off the Northwest coast shows mooring sites planned at water depths of 25 meters, 80 meters and 500 meters in two lines – one off Newport, Oregon, and the other off Grays Harbor, Washington. Gliders will provide additional cross-shelf sampling. (Map courtesy of the Ocean Observatories Initiative's Implementing Organizations)

OCEAN VIEWS

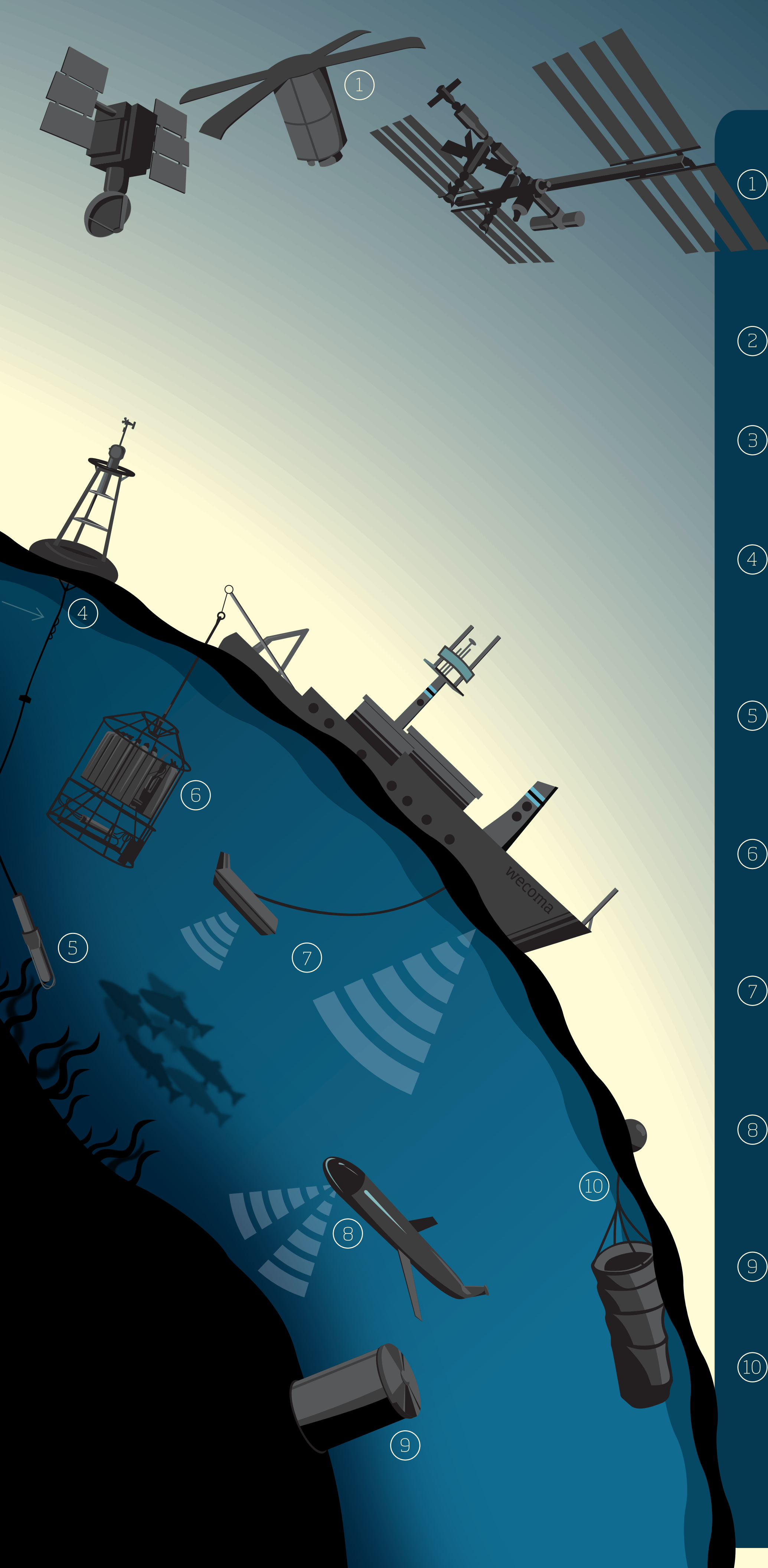
Technology extends our vision. We've always known that the ocean is a dynamic environment, but satellite-borne sensors, sonar, time-lapse video, moored buoys and autonomous gliders are revealing new details: fish, squid and whales in unexpected places; rumblings that foretell the creation of the seafloor; wind-driven surface currents; nitrogen-fixing microbes; circulating rings of water; shifting concentrations of chlorophyll that may signal plankton blooms.

Scientists have far more devices in their toolbox than when OSU oceanographer Wayne Burt performed his initial measurements in Yaquina Bay more than 50 years ago. New technologies detect physical and chemical patterns that set the stage for ocean life, most of which is invisible to our eyes. Small-scale eddies spin off the south-running California Current. Upwelling water drives plankton blooms. Today, OSU partners with the University of Washington, Woods Hole Oceanographic Institution, and the University of California San Diego to lead development of a new ocean observing system that will be deployed off the Northwest coast.

Coast-to-Coast, Ocean-to-Ocean

OSU emeritus professor Tim Cowles leads development of a global ocean observing network known as the Ocean Observatories Initiative (OOI), funded by the National Science Foundation. Dots on the map indicate regional partners in the Integrated Ocean Observing System, funded by the National Oceanic and Atmospheric Sciences Administration.

(Infographic by 208 Design Studio)



① Satellites
With names such as SeaWiFS (Sea-viewing Wide Field-of-view Sensor) and SeaWinds, satellites track phytoplankton blooms, sea ice, surface winds and oil. From the International Space Station, the Hyperspectral Imager for the Coastal Ocean, or HICO, detects light across the electromagnetic spectrum for coastal analysis.

② Radiowave System
Land-based high-frequency radio waves can detect the speed and direction of ocean currents up to 200 kilometers from shore.

③ Argus Imaging System
From bluff tops and buildings, the Argus video observation system creates time-lapse images of surf and sand movements that help scientists analyze the dynamic processes that build and erode shorelines.

④ Moored Buoys
Moored to the seafloor, sensor-equipped buoys collect data 24/7 on chemical, physical and biological ocean properties. Along the Equator, buoy arrays reveal wind and temperature patterns that signal El Nino events. A new moored buoy array is planned for the Pacific Northwest coast as part of OOI.

⑤ Hydrophones
The sea is full of sound: undersea earthquakes, whale calls, massive icebergs scraping the seafloor. Hydrophone data from systems deployed by the U.S. Navy and OSU reveal details about the timing and intensity of these events.

⑥ Water Profiler
Deployed from a ship, a multisensor instrument and sampler provides a detailed look at water properties from the surface to the sea floor. Such direct measurements help to validate data from autonomous and remote sensors.

⑦ Acoustics
OSU researchers use sonar signals to show the ocean ecosystem at work. Using multiple frequencies, their research reveals fish and squid feeding, dolphins cooperating and plankton aggregating. Multibeam sonar emits a fan-shaped beam that can be used to map the seafloor.

⑧ Gliders
Autonomous gliders collect data about the chemical and physical properties of seawater. Equipped with satellite cell phone, GPS antennae and a buoyancy-driven propulsion system, they are capable of diving and surfacing on their own and can stay at sea for up to six months.

⑨ Seismometers
Seafloor seismometers reveal movements and stresses under the coastal ocean. Earthscope researchers will deploy a new seismometer array off the West Coast in 2011.

⑩ Surface Drifters
Drifters carry instruments that relay location and water temperature. Thousands have been deployed throughout the world's oceans. Released off the Oregon Coast, they may travel far to the south in spring and early summer and reach as far west as Hawaii. In winter, they can travel as far north as Alaska.

Balance of Power

OSU helps forge national marine energy policy

BY KATE SINNER | DIRECTOR OF FEDERAL RELATIONS

RENEWABLE OCEAN WAVE ENERGY SEEMS like a natural. It promises jobs for Oregon and carbon-free power for the nation. It can reduce our dependence on foreign oil and contribute to economic development. But before we can realize that potential, we need to be careful to find a balance. In an ideal world, offshore wave energy buoy arrays would be placed where they don't constrain fishermen and crabbers and or harm fish and marine mammals. We need to do enough research to know that sea life — and the people who depend on it — will not be compromised.

As I coordinate Oregon State University's government relations in Washington, D.C., I work with OSU faculty members — some of the nation's top experts — in marine ecology, coastal geophysics and wave energy engineering. Oregon Sea Grant adds strong relationships with community groups and the fishing industry. It's no exaggeration to say that OSU is regarded as the national thought-leader in marine renewable energy. The university uses its deep knowledge and expertise to assist Congress and federal agencies in shaping policy, defining research areas in marine energy and advocating for necessary funding levels.

Renewable energy is both a national and international priority. In 2005, when the 109th Congress wrote and debated the Energy Policy Act, OSU researchers were publishing papers on wave energy. Both OSU and Congress saw the potential of this research and included the creation of marine renewable energy centers in the bill. Our advocacy effort included strategizing with policymakers and providing expert testimony. Much work by key individuals at OSU and in the office of former Rep. Darlene Hooley and her staff led to the creation of these competitive U.S. Department of Energy (DOE) centers.

While the establishment of the centers was a significant accomplishment, it took a few years of strong advocacy with DOE and Congress to appropriate funding. Once that was done, OSU researchers partnered with the University of Washington to respond to requests for research proposals. Ultimately OSU was awarded one of only two national centers, the Northwest National Marine Renewable Energy Center (NNMREC). NNMREC's goal is to lead the nation's research in marine renewable energy with OSU focusing on wave energy and with UW working on tidal. The initial DOE award was a commitment of $6.25 million in federal funds over five years.

Illustration: Chris Buzelli

In 2010, OSU worked with Capitol Hill to develop a broad marine renewable energy policy. The result is HR 6344, the Marine and Hydrokinetic Renewable Energy Promotion Act of 2010. This bill contains authorization of marine renewable energy-related programs ranging from research and development to commercial application and includes increased authorizations for test centers, including NNMREC.

In addition, with leadership from the Ocean Renewable Energy Consortium, of which OSU is a member, the DOE budget for ocean renewable energy programs grew from $10 million in FY 2008 to $48 million in FY 2010. Over those years, NNMREC has competed for and won additional DOE funds.

This isn't the only area in which OSU has been active in Washington. We are often called upon to provide input on national policy matters with significant budget implications. When the House Science and Technology Committee was marking up a nuclear energy research and development bill, we helped to refine some of the provisions. OSU faculty members have provided expertise on forestry, climate change, agriculture, fish and wildlife, the oceans, nanotechnology and aging.

OSU leadership in these areas and our advocacy for key federal research budgets is helping to address national priorities. These initiatives have the additional benefit of supporting students who have opportunities to participate in groundbreaking studies that will achieve balance in our approach to renewable energy. OSU experts are shaping the nation's research agenda for years to come.

"Many oceanographic processes — and the natural history of microbial plankton is no exception — are veiled by the vastness and complexity of the oceans," Stephen Giovannoni says. (Photo: Karl Maasdam)

Surprise in the Sargasso

Stephen Giovannoni opens a new window on the sea

MICROBES ARE MASTERS OF ADAPTATION.

In some of Earth's most extreme environments — Antarctica's frigid ice fields, Yellowstone's sulfuric hot springs, Crater Lake's lightless depths, the oceans' deep-sea basalts — Stephen Giovannoni has discovered thriving communities of bacteria. As the holder of the Emile F. Pernot Distinguished Professorship in Microbiology, he has discovered some of the most abundant life forms on the planet.

About two decades ago, the Oregon State University microbiologist went looking for microscopic master-adapters in yet another place thought to be inhospitable to life: the clear, still waters of the Sargasso Sea south of Bermuda. There, he made a remarkable find. Not only do bacterioplankton (ocean-drifting bacteria) live in this sea once considered a desert, they're everywhere. It turns out that this newly found branch of bacteria, named SAR for the Sargasso, is among the most plentiful — and thus evolutionarily successful — life forms on the planet.

"SAR11 is ridiculously abundant," Giovannoni says, referring to the first SAR strain identified. In fact, the species came to be called *Pelagibacter ubique* ("ubiquitous ocean bacterium") when it started turning up in seawater samples worldwide. "They have been present in more than 50 studies from around the globe and account for 25 percent of all the genes found in these studies."

It had eluded detection mainly because of its diminutive size — small even for a microbe. "SAR11 was basically invisible before," Giovannoni says, explaining that the key to its success was simplicity and efficiency. "SAR11 is just better than any other organism at capturing the traces of organic matter dissolved in the oceans."

After this astounding discovery in 2002, Giovannoni's lab devised novel technologies for growing these kinds of extra-tiny organisms without Petri dishes. Using gene cloning and DNA sequencing, he and his colleagues have so far sequenced 27 hard-to-grow microorganisms never before described. They have shipped samples to scientists all over the world.

"Our research has led to a general appreciation of how important these previously unknown organisms are to global ecology," says Giovannoni. Support from the Emile F. Pernot fund, the National Science Foundation and the Gordon and Betty Moore Foundation have been key. (Emile Pernot helped to establish OSU's Department of Microbiology. The professorship created by his daughter Mabel Pernot is awarded on a rotating basis and will next be held by Theo Dreher, department chair.)

To figure out how marine microbes compete for and adapt to spatial, temporal and seasonal niches and how they contribute to the cycling of carbon in the oceans, Giovannoni is looking at everything from marine snow (carbon-carrying particles that sink into deeper ocean layers) to spring upwelling and summer stratification to species richness (total species in a sample) and surface warming.

"Dynamic interactions between these marine microorganisms lie at the heart of the carbon cycle," the researcher says. "But progress toward understanding these interactions has been slow to emerge because of the complexity of microbial community ecology."

The Campaign for OSU
THIS AMAZING PLACE
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For information about supporting research and teaching through faculty endowments, visit *CampaignforOSU.org* or contact the OSU Foundation at 800-354-7281.

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Port Orford dock worker Faron Busso holds a rougheye rockfish, one of many species that live in the temperate reefs off the southern Oregon Coast. See "Lines in the Water," Page 14. (Photo: Heath Korvola)

Listen to OSU researchers, follow their stories and see photos and videos at **oregonstate.edu/terra**